Customer Energy Efficiency Program
Measurement and Evaluation Program

# EVALUATION OF PACIFIC GAS & ELECTRIC COMPANY'S PRE-1998 COMMERCIAL ENERGY EFFICIENCY INCENTIVES PROGRAM CARRY-OVER: HVAC TECHNOLOGIES

***PG&E Study ID number: 404B***

***March 1, 2000***

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# EVALUATION OF PACIFIC GAS & ELECTRIC COMPANY'S PRE-1998 COMMERCIAL ENERGY EFFICIENCY INCENTIVES PROGRAM CARRY-OVER FOR HVAC TECHNOLOGIES

*PG&E Study ID number: 404B*

## Purpose of Study

This study was conducted in compliance with the requirements specified in "Protocols and Procedures for the Verification of Costs, Benefits, and Shareholders Earnings from Demand-Side Management Programs" (Protocols), as adopted by California Public Utilities Commission Decision 93-05-063, revised March 1998, pursuant to Decisions 94-05-063, 94-10-059, 94-12-021, 95-12-054, 96-12-079 and 98-03-063.

This study evaluated the gross and net energy savings from HVAC energy efficiency technologies for which rebates were paid in 1998 by Pacific Gas & Electric Company's Commercial Energy Efficiency Incentive (CEEI) Programs. These retrofits were performed under CEEI programs offered from 1994 through 1997. Retrofits were performed under three different PG&E programs: the Retrofit Express (RE), Retrofit Efficiency Options (REO), and Advanced Performance Options (APO) Programs.

## Methodology

For this evaluation, there were two types of primary data collected: telephone survey data and on-site audit data. An integrated sample design was implemented for the lighting and HVAC end uses, due to the number of participant crossover among these end uses. There were a total of 137 HVAC sites, 99 standard and 38 custom, that received a rebate from PG&E in 1998. A complete census was conducted and 81 sample points were collected. A non-participant sample was developed based upon the business type and usage strata distribution that resulted from the participant sample allocation. The HVAC end-use included 81 HVAC participant and 589 nonparticipant telephone surveys and 64 on-site audits.

An integrated evaluation approach employed engineering, billing regression and net-to-gross (NTG) analyses. Engineering and statistically adjusted engineering (SAE) estimates were used to develop per participant gross energy, demand, and therm impacts for specified time-of-use costing periods. The engineering analysis combined information from telephone surveys with detailed on-site audit data to develop unadjusted engineering impacts. A billing regression analysis was employed to model the differences in customers' energy usage between pre- and post-installation periods. The model was specified using actual customer billing data and independent variables that explain changes in customers' energy usage including engineering estimates of unadjusted savings.

Three separate models were implemented to estimate the components of the NTG ratio (free-ridership and spillover): a model based on self-reports, a net billing analysis model applying a double inverse Mills ratio (estimating free-ridership only), and a two-stage discrete choice model. The final NTG ratios applied to the ex post gross impacts are based on the results of the self-report model. Discrete choice results were only obtained for the CAC technology segment due to the small available sample, and the results were not supported by either the Mills ratio or the self report result. To be conservative and consistent, the self-report estimates of NTG were applied to all of the HVAC technology segments.

## Study Results

The results of the analyses for the HVAC technologies are summarized below:

| | Gross Savings | Gross Realization Rate | Net-To-Gross 1-FR | Spillover | NTG Ratio | Net Savings | Net Realization Rate |
|---|---|---|---|---|---|---|---|
| | | | EX ANTE | | | | |
| kW | 3,159 | - | 0.652 | 0.100 | 0.752 | 2,376 | - |
| kWh | 20,671,794 | - | 0.651 | 0.100 | 0.751 | 15,525,132 | - |
| Therms | 575,787 | - | 0.650 | 0.100 | 0.750 | 431,840 | - |
| | | | EX POST | | | | |
| kW | 3,538 | 1.120 | 0.728 | 0.140 | 0.868 | 3,071 | 1.293 |
| kWh | 13,659,972 | 0.661 | 0.729 | 0.140 | 0.869 | 11,865,436 | 0.764 |
| Therms | 489,681 | 0.850 | 0.762 | 0.140 | 0.902 | 441,701 | 1.023 |

## Regulatory Waivers and Filing Variances

The CADMAC approved a waiver on May 20, 1999, that allows the use of self - report based algorithms to estimate free ridership and spillover effects in the event discrete choice and LIRM models fail to produce statistically reliable results.

There were no E-Table variances.

# *EVALUATION OF PG&E'S PRE-1998 COMMERCIAL EEI PROGRAM CARRY-OVER HVAC TECHNOLOGIES*

## *PG&E Study ID#: 404B*

## *FINAL REPORT*

*March 1, 2000*

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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 Pacific Gas & Electric Company's (PG&E's) Pre-1998 Commercial Energy Efficiency Incentive (CEEI) Program Carry-Over, referred to in this report as the HVAC Program. This evaluation covers HVAC technology retrofits that were rebated during 1998, under CEEI programs offered from 1994 through 1997. These retrofits were performed under three different PG&E programs: the Retrofit Express (RE), the Retrofit Efficiency Options (REO), and the Advanced Performance Options (APO) Programs. The results are presented in two sections: Evaluation Results Summary (covering the numerical results of the study) and Major Findings.

## 1.1 EVALUATION RESULTS SUMMARY

The evaluation results are summarized in terms of energy savings (kWh), demand savings (kW), therms impacts, and realization rates. Realization rates are defined as the ratio of the evaluation results (ex post) to the program design estimates (ex ante). All of 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** | 3,159 | - | 0.652 | 0.100 | 0.752 | 2,376 | - |
| **kWh** | 20,671,794 | - | 0.651 | 0.100 | 0.751 | 15,525,132 | - |
| **Therms** | 575,787 | - | 0.650 | 0.100 | 0.750 | 431,840 | - |
| **EX POST** | | | | | | | |
| **kW** | 3,538 | 1.120 | 0.728 | 0.140 | 0.868 | 3,071 | 1.293 |
| **kWh** | 13,659,972 | 0.661 | 0.729 | 0.140 | 0.869 | 11,865,436 | 0.764 |
| **Therms** | 489,681 | 0.850 | 0.762 | 0.140 | 0.902 | 441,701 | 1.023 |

Overall, net ex post energy and therm impacts are relatively similar to ex ante estimates, while ex post net demand impacts are somewhat higher. Ex post and ex ante therm impacts are fairly consistent overall. Ex post gross energy impact estimates are measurably lower than ex ante, however the higher ex post NTG adjustment results in a net realization rate that is consistent with ex ante estimates. Ex post gross demand estimates are 12 percent higher than ex ante, which is exaggerated to 29 percent by the larger ex post NTG.

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:** Nearly 87 percent of program energy savings are from HVAC technologies installed through the APO program. Almost all of the program therm savings are from HVAC technologies installed through the APO program, although a small therm savings was also generated in the REO program.

**Gross Impacts**: Overall ex post gross impacts were 34 percent less than the ex ante estimates for energy, and 12 percent higher for demand. The lower energy estimates were attributable primarily to lower ex post impacts for the Water Chillers and other Custom measures within the APO and REO programs. The ex post estimates for these measures are based upon calibrated engineering results and the SAE results. The engineering analyses included a careful review of the original application calculations, an on-site audit to supplement the application information. In general, the differences between ex post impacts and ex ante estimates are due to improved information contributing to the ex post estimates or updated calculation methods. The SAE adjustment was 0.76 for these measures, contributing to the relatively low gross impact calculations relative to ex ante.

**Net Impacts**: The net ex post impacts are lower than net ex ante estimates by 24 percent for energy, 2 percent for therms, and are 29 percent higher for demand. These results are driven by the ex ante and ex post net-to-gross (NTG) ratios. The ex ante NTG ratio was 0.75 for both demand and energy, while the ex post NTG ratio applied was much larger: 0.87 for energy and demand, and 0.90 for therms. These larger estimates measurably increase the net program effects.

## *1.2 MAJOR FINDINGS*

The key findings are summarized as follows:

- Overall, PG&E's ex ante estimates for demand and therm impacts for commercial HVAC technologies paid under the pre-1998 program carry-over were conservative, resulting in net realization rates exceeding one. At the same time, ex ante estimates of energy impacts were somewhat aggressive, and have a resulting net realization rate well below one.

- Gross ex post energy impacts were measurably lower than the ex ante estimates. This was attributable to engineering analyses of Water Chiller and other Customized APO and REO installations that found lower gross energy impacts. In addition, impacts were further reduced for these measures because the billing analysis detected less savings than predicted by engineering estimates.

- Larger NTG ratios resulted in larger ex post net realization rates relative to gross. For energy and therm impacts, this brought the net realization rates closer to one. For demand impacts, higher gross ex post values were exaggerated by the NTG adjustments, resulting in a net realization rate well above one.

# 2 INTRODUCTION

This report summarizes the impact evaluation of Pacific Gas & Electric Company's (PG&E's) Pre-1998 Commercial Energy Efficiency Incentive (CEEI) Program Carry-Over for HVAC technologies (the HVAC Evaluation). These technologies are covered by three separate program options, the Retrofit Express (RE) Program, the Retrofit Efficiency Options (REO) Program, and the Advanced Performance Options (APO) Program.

The evaluation effort includes customers who were paid rebates in 1998, but participated under the 1994-1997 CEEI programs. The APO program comprised only 29 paid applications, but constituted approximately 86% of the total energy impacts. The REO, APO, and RE programs are summarized below.

## 2.1 PROGRAM DESCRIPTIONS

### 2.1.1 The Retrofit Efficiency Options Program

The REO program included nine HVAC technologies, that can be summarized into five 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 |
| High efficiency gas boilers |

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.

### 2.1.2 The Advanced Performance Options Program

The APO program included all HVAC technologies that were not covered under other PG&E rebate programs. Typically, APO projects included, but were not limited to, one or more of the following technologies:

**Technology**

Energy Management Systems

Installation of high efficiency water chillers

Variable air volume supply systems, which replace constant air volume supply systems

Evaporative cooling towers

Heat Exchangers

The APO program targeted commercial, industrial, and agricultural market segments most likely to benefit from these unique projects. 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 that required a customized evaluation approach, as opposed to a prescriptive approach.

### *2.1.3 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 *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, and APO programs, and for which rebates were *paid* during calendar year 1998.

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

### *2.2.1 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 and APO HVAC technologies paid in 1998, 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 and APO HVAC technologies paid in 1998, 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 and APO 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 Program's 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, explained differences between ex ante estimates and ex post results.

### *2.2.2 Timing*

The 1998 HVAC Evaluation began in May 1999, completed the planning stage in May 1999, executed data collection between May and October 1999, and completed the analysis and reporting phase in February 2000.

### *2.2.3 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.

## *2.3 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.

### *2.3.1 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

[1] California Public Utilities Commission Decision 93-05-063, Revised March 1998, Pursuant to Decisions 94-05-063, 94-10-059, 94-12-021, 95-12-054, 96-12-079, and 98-03-063.

Marketing Decision Support System (MDSS), paper copies of REO and APO 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.

*PG&E 1997 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. The 1997 version was used rather than the 1998 version because the evaluation is for carry-over participants.

*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 REO and APO Paper Application Files* - QC requested and received complete copies of application files for all REO and APO participants. The REO applications provided additional information not found in the MDSS, predominantly on attachment equipment invoices (such as horsepower, and SEER ratings). The APO 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) APO files had enough information in the documentation to support an engineering review of the impact calculations. A thorough assessment of each APO application was conducted, and unadjusted engineering estimates of impact and savings were calculated for each APO participant.

[2] PG&E 1997 Customer Energy Efficiency Programs Advice Letter No. 1978-G/1608-E, filed October 1996.

*1996 Commercial HVAC Results* - End-use monitored data collected on adjustable speed drives (ASDs) for the 1996 Commercial HVAC Evaluation were utilized in the estimate of unadjusted engineering estimates for ASDs.

*1997 End-Use Logger Results* - A total of 30 sites with central air conditioners (CAC) were loggered. Within that population, specific business types (offices, retail businesses and schools) were identified as segments that could significantly contribute to a calibrated engineering model. A total of 30 sites were recruited and loggers installed for a period of 3 months. This data was used in the engineering analysis for the CAC technology segment ex post energy and demand impact and savings calculations.

**Primary Data Collected**

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

*On-Site Audits* - A total of 64 customer sites were visited by a QC engineer to gather site-specific data used in support of the engineering 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.

*Telephone Survey Data* - A significantly larger telephone survey sample was collected. A total of 76 participant, 589 nonparticipant, and 4,333 canvass surveys were completed to gather customer profiles used in all of the analyses. The participant survey was designed to gather 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.

### *2.3.2 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:

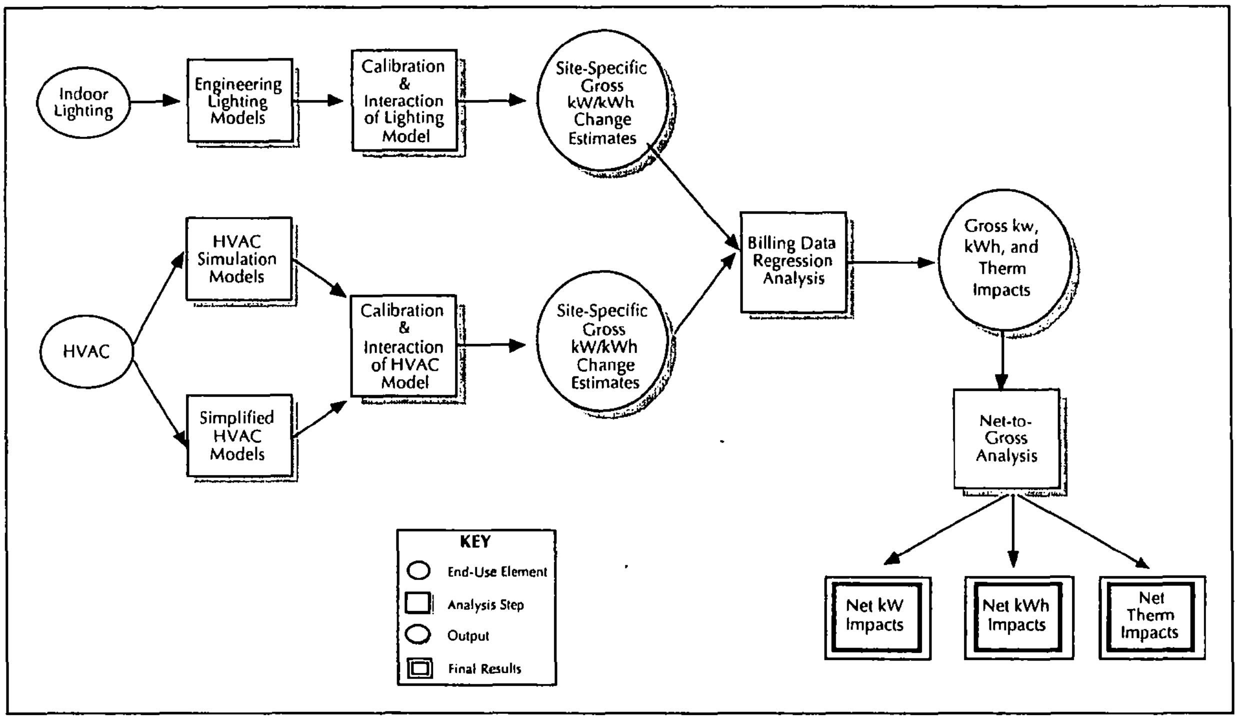
Net Impact = (Operating Impact) * (Operating Factor) * (SAE Coefficient) * (Net-to-Gross)

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. First, engineering estimates were developed for each participant. Second, these estimates were 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, School, 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 25 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 outputs 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 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 attributable 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 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 adoptions, only CAC technologies were modeled. The remaining estimates of net were based on the self-report model. Also, the California DSM Measurement Advisory Committee (CADMAC) approved a waiver that allows the use of self -report based algorithms to estimate free-ridership and spillover effects in the event discrete choice and LIRM models fail to produce statistically reliable results. (The approved waiver is presented in Attachment 5.)

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.

## *2.4 REPORT LAYOUT*

This report presents the results of the HVAC Evaluation. It is divided into four sections, plus attachments and 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. *Attachment 1* is a collection custom site write-ups on each site reviewed and/or audited by QC engineers. *Attachment 2* is the results of the engineering algorithm review of standard (RE) HVAC measures. *Attachment 3* is 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. *Attachment 5* contains a waiver accepted by the ORA for the Pre-1998 CEEI Program Carry-Over evaluation. 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 Pre-1998 Pacific Gas & Electric Company (PG&E) Commercial Energy Efficiency Incentives (CEEI) Program Carry-Over 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 (*Section 3.4)* are discussed.

## 3.1 SAMPLE DESIGN

This section presents the sample design for the HVAC Evaluation. Due to the limited number of available sample, a census of the population was used for the telephone survey. 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), and Advanced Performance Options (APO) Programs are maintained as part of PG&E's Marketing Decision Support System (MDSS). Henceforth, the RE program components (excluding Chillers and including ASDs) 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 1999. 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

Program participants who were paid a rebate in 1998 were in most part carry-over applicants. Their projects were initiated prior to 1997 but they only applied or received a rebate in 1998 when their projects reached the final implementation stage. There were a total of 137 HVAC sites, 99 standards and 38 customs, that received a rebate from PG&E in 1998. A complete census of the population was needed to meet the goals of the telephone survey.

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.
- Maximize available 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 13 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***
***1998 Commercial HVAC Segmentation and Distribution of Unique Sites***

| Technology | Business Type | Office | Retail | College/Univ | School | Grocery | Restaurant | Health Care | Hotel/Motel | Warehouse | Personal Svcs. | Comm. Svcs. | Misc. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HVAC End Use Unique Sites | | 54 | 5 | 8 | 7 | 1 | 7 | 13 | 8 | 2 | 11 | 18 | 3 | 137 |
| HVAC | Central A/C | 19 | 4 | 1 | 5 | 0 | 5 | 5 | 1 | 0 | 5 | 11 | 3 | 59 |
| | Adjustable Speed Drives | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 10 |
| | Package Terminal A/C | 2 | 0 | 0 | 1 | 0 | 1 | 0 | 6 | 0 | 0 | 0 | 0 | 10 |
| | Set-Back Thermostat | 5 | 3 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 6 | 1 | 18 |
| | Reflective Window Film | 12 | 0 | 1 | 0 | 0 | 1 | 3 | 0 | 2 | 1 | 2 | 0 | 22 |
| | Water Chillers | 8 | 0 | 2 | 1 | 0 | 0 | 2 | 0 | 0 | 1 | 3 | 0 | 17 |
| | Customized EMS | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 5 |
| | Customized Controls | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 5 |
| | Convert To VAV | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | Other Customized Equip | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 5 |
| | Cooling Towers | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 4 |
| | High Efficiency Gas Boilers | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | Other HVAC Technologies | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 |

Annual energy consumption values were used to group customers into four usage/size strata based upon a Dalenius-Hodges[1] 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. (Please note that in Exhibit 3-1, sites may contain more than one technology; therefore, the total row is less than or equal to column sum.) 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.

### *3.1.5 Sample Allocation*

For the HVAC Evaluation, there were two types of primary data collected: telephone survey data and on-site audit 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 the 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. With an available sample frame of 137 unique HVAC sites, a census of all eligible participants was taken for the telephone survey. This is Protocol compliant.

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

### Participant Standard On-Site Samples

The on-site audits was designed to collect detailed information regarding installed HVAC technologies under the Program. The on-site audit data was used to validate the telephone survey data for information such as operating hours and factors to be used in the engineering analysis. The on-site samples were drawn for only certain technologies which contributed the majority of the gross impacts and avoided costs. For this evaluation, the sample design focused on Central Air Conditioners (S160) and Set-Back Thermostat (S18) technologies.

Exhibit 3-2 summarizes the standard on-site sample allocation for the HVAC end use. A total of 21 standard on-site audits were collected. The on-site audits were grouped into analysis segments of similar climate conditions. Grouping sites into segments allowed analysis to yield more significant results.

*Exhibit 3-2*
*Proposed Standard Measure HVAC On-Sites*
*In Support of DOE-2 Model Development*

| Business Type | Climate Zone | Number of Avaliable Sites | Standard On-Sites |
|---|---|---|---|
| Office | 2, 3, 4 | 25 | 11 |
| Office | 11, 12, 13 | 11 | 5 |
| Retail | 11, 12, 13 | 3 | 2 |
| School | 11, 12, 13 | 12 | 3 |
| **TOTAL** | | **51** | **21** |

### Participant Custom On-Site Samples

The custom on-site sample consists of technologies with unique operating characteristics and technologies with complex installations under PG&E's custom programs. Custom HVAC measures were installed in only 38 sites. Therefore, a census of these customers was attempted during on-site recruitment with the goal of completing 25. The Custom measures are distributed across the 38 sites as illustrated below in Exhibit 3-3.

*Exhibit 3-3*
*Available Custom Measure Sample Frame*

| Program | Technology Group | Number of Avaliable Sites |
|---|---|---|
| Retrofit Express | Water Chillers | 1 |
| Retrofit Express Options | Water Chillers | 2 |
| | Cooling Towers | 4 |
| | High Efficiency Gas Boilers | 1 |
| Advanced Performance Options | Water Chillers | 11 |
| | Customized EMS | 5 |
| | Customized Controls | 5 |
| | Convert to VAV | 2 |
| | Other Customized Equipment | 5 |
| | Other HVAC Technologies | 2 |
| **TOTAL** | | **38** |

**Comparison (nonparticipant) Sample**

The primary objective of the nonparticipant telephone sample is to provide a control group for the net and gross billing analyses. The final comparison group sample frame consists of 192,689 commercial customers drawn from an eligible population of over 400,000. 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 annual non-missing, non-zero usage values for 1997, 1998 and 1999. Customers with zero, or missing billing data, were removed from the sample.

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. The final sample design includes 48 segments classified by size according to energy usage.

Exhibit 3-4 below illustrates the 48 segments by business type and size, 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 desired nonparticipant quota was 500 points, but the quota was targeted at approximately 600 points with the assumption that for certain segments, such as the "Very Large" segment, the quota would not be filled. The final sample allocation was randomly selected within each customer segment.

***Exhibit 3-4***
***Nonparticipant Survey Quotas***
***Telephone Survey Sample***

| Small | | | | Medium | | | | Large | | | | Very Large | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Business Type | Quota | Avail. | N | Business Type | Quota | Avail. | N | Business Type | Quota | Avail. | N | Business Type | Quota | Avail. | N |
| Office | 43 | 20,253 | 860 | Office | 37 | 1,416 | 740 | Office | 45 | 775 | 900 | Office | 39 | 148 | 780 |
| Retail | 30 | 19,857 | 600 | Retail | 30 | 1,403 | 600 | Retail | 11 | 508 | 220 | Retail | 4 | 38 | 80 |
| Col/Univ | 0 | 449 | 0 | Col/Univ | 2 | 49 | 40 | Col/Univ | 2 | 33 | 40 | Col/Univ | 10 | 25 | 200 |
| School | 18 | 1,807 | 360 | School | 16 | 768 | 320 | School | 20 | 200 | 400 | School | 3 | 7 | 60 |
| Grocery | 11 | 6,228 | 225 | Grocery | 7 | 916 | 150 | Grocery | 11 | 506 | 225 | Grocery | 2 | 19 | 40 |
| Restaurant | 5 | 11,169 | 109 | Restaurant | 14 | 1,794 | 273 | Restaurant | 11 | 85 | 218 | Restaurant | 1 | 0 | 20 |
| Health Care/Hosp | 11 | 7,668 | 210 | Health Care/Hosp | 3 | 467 | 60 | Health Care/Hosp | 16 | 187 | 330 | Health Care/Hosp | 8 | 58 | 160 |
| Hotel/Motel | 16 | 1,753 | 320 | Hotel/Motel | 2 | 363 | 40 | Hotel/Motel | 12 | 125 | 240 | Hotel/Motel | 6 | 30 | 120 |
| Warehouse | 15 | 6,708 | 300 | Warehouse | 8 | 483 | 150 | Warehouse | 8 | 212 | 150 | Warehouse | 1 | 17 | 20 |
| Personal Service | 15 | 12,984 | 300 | Personal Service | 15 | 306 | 300 | Personal Service | 0 | 121 | 0 | Personal Service | 4 | 12 | 80 |
| Community Service | 38 | 15,092 | 760 | Community Service | 11 | 787 | 220 | Community Service | 7 | 321 | 140 | Community Service | 6 | 48 | 120 |
| Misc. Commercial | 25 | 11,719 | 500 | Misc. Commercial | 3 | 692 | 67 | Misc. Commercial | 2 | 380 | 33 | Misc. Commercial | 2 | 95 | 40 |
| SUB-TOTAL | 227 | 115,687 | 4,544 | SUB-TOTAL | 148 | 9,444 | 2,959 | SUB-TOTAL | 145 | 3,453 | 2,897 | SUB-TOTAL | 86 | 497 | 1,720 |
| GRAND TOTAL | 606 | 129,081 | 12,120 | | | | | | | | | | | | |

*Gray cells indicate nonparticipant segments where the available population to quota ratio is low.

The canvass sample included 50,000 randomly drawn customers within PG&E's service territory. It's primary function was to support the net-to-gross analysis by identifying nonparticipants who have installed program qualifying measures outside of the rebate programs. The sample design focused on identifying only nonparticipants who were not rebated in 1998. From a sample of 50,000 customers, the sample quota was targeted for 4,000 total completes with about 500 of the 4,000 having made lighting or HVAC changes.

### *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 3-5 by end-use element.

**Telephone Survey Sample** – Telephone surveys were collected for a total of 855 customers, 266 of which were participants, with the remaining 589 in the comparison group. Among the 266 participants, 76 were HVAC participants. In addition, another 4,333 customers were contacted as part of the canvass survey. Because of the overlap among HVAC and Lighting participants, a single instrument was used to conduct both telephone surveys.

*Exhibit 3-5*
***Data Collected by Program and End Use***

| Program | End Use | Available Population | Data Collected: Telephone Survey | Data Collected: On-Site Audits | Data Used in HVAC Analysis: Telephone Survey | Data Used in HVAC Analysis: On-Site Audits |
|---|---|---|---|---|---|---|
| Custom | Lighting | - | - | - | - | - |
| | HVAC | 38 | 5 | 26 | 5 | 26 |
| Retrofit | Lighting | 428 | 190 | 158 | 190 | - |
| | HVAC | 137 | 76 | 38 | 76 | 38 |
| Total | Lighting | 428 | 190 | 158 | 190 | - |
| | HVAC | 175 | 81 | 64 | 76 | 64 |
| Total Participants | | 547 | 255 | 220 | 255 | 64 |
| Total Nonparticipants | | 396,870 | 589 | - | 589 | - |
| Total Sites | | 397,417 | 844 | 220 | 844 | 64 |

**On-site Audit Sample** – Within the Custom program, a census of HVAC participants was attempted for recruitment, with a total of 26 on-site audits completed. An additional 38 Standard measure on-sites were completed amongst sites that installed HVAC technologies. In all, a total of 64 HVAC on-site surveys were conducted.

### *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 was calculated using the following procedure. First, the 1997 annual energy consumption was computed for all participants in the analysis dataset.

Next, four strata were constructed based on a customers' annual usage using the Delanius-Hodges procedure. Then, the program level mean and standard error were calculated using classic stratified sample techniques[2]. Finally, the relative precision at a 90 percent confidence level was 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 because of the significant influence they have over the relative precision estimate, and because these customers were excluded from the SAE analysis.

By survey, the following relative precision was achieved:

- For nonparticipants, the relative precision is 5.0 percent based upon a survey sample of 534[3].

[2] Ibid. pp. 91-95

[3] The nonparticipant sample size, 534, is the total sample of 589 less 55 very large customers.

- For HVAC, the relative precision is 7.2 percent based upon a survey sample of 60[4].

Exhibit 3-6 presents the stratum-level sample size, sample weight, sample mean, and estimated standard errors for each end use evaluated.

*Exhibit 3-6*
*Telephone Sample Relative Precision Levels*

***Nonparticipants***

| Weight | Sample | Mean | STD | Standard Error | Relative Precision |
|---|---|---|---|---|---|
| 90.5% | 238 | 41,641 | 40,421 | 2,617 | 10.3% |
| 6.9% | 150 | 314,202 | 111,989 | 9,041 | 4.7% |
| 2.5% | 146 | 1,228,131 | 618,554 | 49,644 | 6.6% |
| **TOTAL** | 534 | 90,424 | | 2,751 | 5.0% |
| **Large Customers** | | | | | |
| Population = 710 | 55 | 6,027,677 | 3,454,642 | 429,739 | 11.7% |

***HVAC Participants***

| Weight | Sample | Mean | STD | Standard Error | Relative Precision |
|---|---|---|---|---|---|
| 48.6% | 28 | 88,709 | 62,755 | 5,710 | 10.6% |
| 21.6% | 14 | 298,073 | 61,304 | 6,827 | 3.8% |
| 29.7% | 18 | 1,541,461 | 773,853 | 82,909 | 8.8% |
| **TOTAL** | 60 | 565,876 | | 24,848 | 7.2% |
| **Large Customers** | | | | | |
| Population = 26 | 16 | 8,130,176 | 5,102,548 | 490,630 | 9.9% |

### *3.1.8 Demonstration of Protocol Compliance*

#### Sampling Procedures Adopted

The sample design follows the rules established by the CPUC in the March 1998 revisions to the "Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand Side Management Programs."

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[4] The HVAC participant sample size, 60, is the total sample of 76 less 16 very large customers.

## 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. However, if a program has fewer than 450 participants then a census of the participants must be taken. The analysis dataset was derived from a census of the participant population.

As illustrated in Exhibit 3-6, the sample collected for the HVAC end use achieved a relative precision of at least 6 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 3-6 illustrates a relative precision of at least 7 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 1999, which ensures an adequate pre- and post-installation billing period for customers who installed applicable measures between 1996 and 1999.

### *3.2 ENGINEERING ANALYSIS*

The technical approach and engineering results that support realized gross impacts in the 1998 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 1998 evaluation.

Additional documentation for the custom on-site analyses is 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 REO and APO program participants or participants who installed "custom[5]" measures are 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 three separate PG&E programs, Retrofit Express (RE), Retrofit Efficiency Options (REO), and Advanced Performance Options (APO). Where measures offered in different programs are similar (such as water chillers and adjustable speed drives), identical analysis methods were applied across all programs.

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

Listed below are each measure type studied 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 logger 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. A calibrated engineering model was used to develop estimates based on 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, and APO), Convert to VAV, Cooling Towers, Customized EMS, and other customized 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), including Window Film, Package Terminals, Set Back Thermostats, Time Clocks, and Evaporative Coolers.

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 end-use logger data, and 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 (conducted in paid-year 1997 evaluation)
- Verify and/or update inputs with 1998 on-site data
- Calibrate DOE-2 models (conducted in paid-year 1997 evaluation)
- Create undiversified and diversified energy models
- Calculate CAC energy savings
- Compute energy and demand impacts

Paid year 1997 on-site audit data were used to develop DOE-2 models of office, school, and retail facilities that participated in the program. The key inputs to the models were compared to values obtained from paid year 1998 on-site audit data. Due to the limited sample size for paid year 1998, no changes were made to the models. These models were then calibrated using end-use logger data from 30 sites, 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 weather data were analyzed to determine the number of DOE-2.1E prototypes needed to represent typical participating office, school, and retail facilities. The primary variables reviewed were conditioned square footage, cooling degree days across climate zone, and building size and construction characteristics.

For CAC Measures it was determined that Office participants could be represented by two prototypes, segmented by climate zones (climate zones 1-5 versus 11-16). There was not sufficient sample to segment School and Retail by climate zone, so both School and Retail are represented by one prototype each.

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.

For the 1998 evaluation, no changes were made to the models. This is mainly due to the limited sample size. There was not enough sample for any of the modeled business types and climate zones to justify changes.

Key characteristics for the four prototypes are detailed in Exhibit 3-7.

### Calibrate DOE-2 Models

To ensure that the modeled results were accurate and reasonable, models were calibrated to end-use logger 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 logger data. Minimum ventilation, miscellaneous equipment watts per square foot, and economizer control strategies were used in calibrating the model.

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[6] This approach is consistent with the approach used for the 1995 and 1996 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.

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.

*Exhibit 3-7*
*Key Characteristics for DOE-2.1E Prototypes*

| Variable | Office03 CAC | Office13 CAC | Retail CAC | School CAC |
|---|---|---|---|---|
| Conditioned Area (Sq Ft) | 41,263 | 5,291 | 4,478 | 8,953 |
| Slab Floor Area (Sq Ft) | 7,749 | 4,565 | 4,063 | 7,737 |
| Gross Wall Area (Sq Ft) | 19,841 | 2,610 | 2,972 | 5,305 |
| Frame Wall Area | 41% | 58% | 34% | 83% |
| Block Wall Area | 59% | 42% | 66% | 17% |
| Frame Insulation | R-3 | R-9 | R-7 | R-4 |
| Block Insulation | R-1 | R-2 | R-1 | R-2 |
| Roof Area (Sq Ft) | 9,045 | 4,692 | 4,364 | 8,895 |
| Roof Insulation | R-7 | R-11 | R-14 | R-19 |
| Ceiling Height (Ft) | 9 | 9 | 11 | 13 |
| Window Type | Single Shaded | Single Shaded | Single Clear | Single Clear |
| Cooling Capacity (Btuh) | 837,122 | 231,917 | 181,565 | 465,744 |
| Number of Occupants | 165 | 19 | 15 | 119 |
| Thermostat Setpoint (°F) | 71 | 74 | 75 | 73 |

## 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, 1998, through September 30, 1999, the post-retrofit period used in the SAE model.

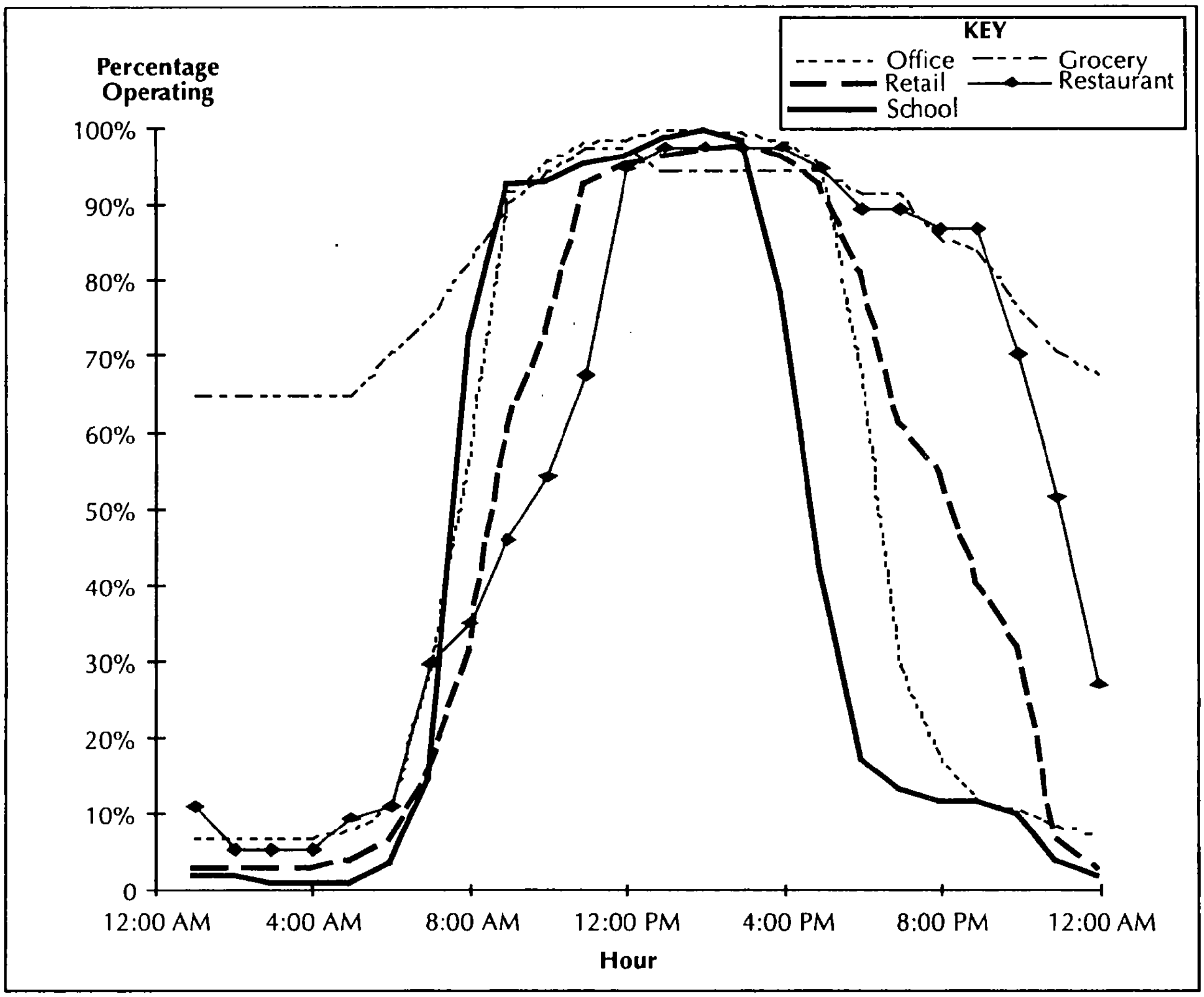
Undiversified CAC savings estimates (used in the SAE model) were generated using the installed efficiencies of the retrofit equipment taken from the MDSS and estimated existing efficiencies based on the size of the retrofit unit. The existing efficiencies used were based on 1988 Title 24 standards, downgraded 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, School, and Retail business types in all climate zones where there was program participation. All other business types are mapped to either the Office, School or Retail prototypes.

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 is a series of hourly loads for CACs adjusted for the occupancy and operational patterns of participants.

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



### 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.

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.

***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.

### 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, 1998 through September 30, 1999; that were then used as inputs to the SAE analysis. The following steps were taken to convert the energy *savings* estimates to *impact* estimates:

**Current CEC** - CEC weather data[7] 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 the logger data. For each loggered CAC unit, the five highest weekday duty cycles occurring between 3 and 4 PM were selected as representing undiversified peak duty cycles. The average of these duty cycles was calculated by business type. In order to develop Coincident Diversity Factors (CDF), the undiversified peak duty cycles by business type were multiplied by operating factors. The operating factors were developed by business type and climate zone, which resulted in CDFs for each combination of business type and climate zone. Demand impacts were computed for each participant in the MDSS using the equation in Exhibit 3-10.

***Exhibit 3-10***
***Equation for Estimating CAC Demand Savings***

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

Where,

$kW_{sav,i,j,k}$ = Peak demand impact for participant I, in business type j, climate zone k;

$U$ = Number of units installed;

$CDF_{j,k}$ = Coincident Diversity Factor for business type j, climate zone k;

$T$ = Number of tons per installed unit;

$EER_1$ = Baseline EER; and,

$EER_{MDSS}$ = Post-retrofit EER.

[7] 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.

### *3.2.3 Adjustable Speed Drives (ASDs) for Ventilation Fans*

Demand and energy impacts for the Adjustable Speed Drive measures for all 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 collected for the 1996 HVAC Evaluation 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. 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.

### 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 equation shown in Exhibit 3-11 was then applied to estimate the percentage of power drawn by the ASD during that interval.

*Exhibit 3-11*
*Baseline Interval Demand Estimate*

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

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

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

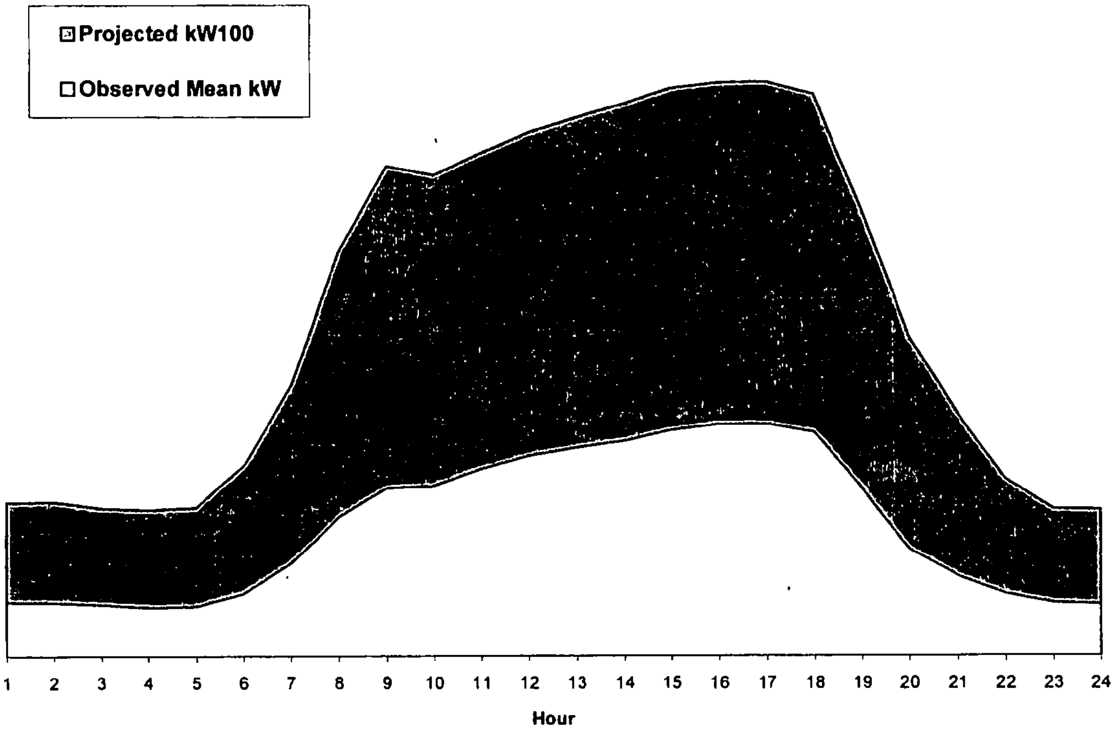
$Hz_i$ = The recorded Hz during interval i;

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.

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




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.

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, 1998 through September 30, 1999. 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 1998-1999 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, 1998, through September 30, 1999; 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.

*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;

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, as shown in Exhibit 3-14.

*Exhibit 3-14*
*Equation for Estimating ASD Demand Impacts*

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

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 and APO technologies were considered part of the "custom" measure segment:

- Chillers;
- Convert to VAV;
- Cooling Towers;
- Customized EMS; and,
- Other Customized Equipment and HVAC Technologies.

Every application that installed a "custom" measure was requested for thorough engineering review. Because only 38 sites installed custom measures, a census was conducted for conducting the on-site audits, which resulted in a total of 28 site visits.

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 both 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, information gathered during on-site visits was not of sufficient quality to justify a revised estimate claim. In these cases, ex ante impact estimates were accepted as accurate.

Attachment 1 contains a summary of information regarding the development of impacts for each custom measure 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. 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 1997 Advice Filing[8]). 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 measure. The summary provides an overview of the algorithm review used to develop 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) can be found in Attachment 2.

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[8] PG&E 1997 Customer Energy Efficiency Programs Advice Letter No. 1978-G/1608-E, filed October 1996.

## 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 Title 20 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.<br><br>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:** | Demand and energy savings were developed on a per ton basis for each climate zone using fan operating characteristics, temperature design conditions, and cooling degree hours. |
| **Comments on Advice Filing Calculations:** | Calculation methods cited in the Advice Filing do not accurately model participant specific retrofits. In some cases, negative demand and energy savings are calculated. |
| **Comments on Advice Filing Inputs:** | The inputs used in the calculations do not account for variations in evaporative cooler fan size. |
| **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. Impacts were developed using motor efficiency values listed in the baseline assumptions for the RE Motors program. |
| **Additional Notes:** | |

**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 Title 20 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.<br><br>Sufficient data are not available to verify either the CDF or the EFLH values used in the calculation.<br><br>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) Pre-1998 CEEI Program Carry-Over. 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 primary 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 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), and Advanced Performance Options (APO) 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 1993 through December 1998.

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 1999 through September 1999. The resulting combined dataset represents the billing series of PG&E prorated monthly usage data for each calendar month from January 1993 to September 1999.

### 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 collected as part of the evaluation for the HVAC Program (except for the Canvass surveys, which do not collect detailed information regarding changes that have occurred at the premise) were used as inputs to the billing regression analysis. Two telephone survey samples totaling 844 sample points (76 of which were HVAC participants and 589 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 76 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,[9] 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

[9] 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.

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 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 | 11 | 1 | 1 | 3 | | 3 | 3 | 1 | | 3 | 5 | | 31 |
| | Adjustable Speed Drives | 3 | | | | | | | | | 1 | | | 4 |
| | Package Terminal A/C | 1 | | | 1 | | | | 4 | | | | | 6 |
| | Set-Back Thermostat | | | | | | | | | | | 1 | | 1 |
| | Reflective Window Film | 6 | | | | | 1 | 2 | | | | 1 | | 10 |
| | Water Chillers | | | | | | | | | | | 1 | | 1 |
| | Other HVAC Technologies | | | | | 1 | | | | | | | | 1 |
| Retrofit Express Program Total | | 21 | 1 | 1 | 4 | 1 | 4 | 5 | 5 | 0 | 4 | 8 | 0 | 54 |
| REO | Adjustable Speed Drives | 1 | | | | | | | | | | | | 1 |
| | Water Chillers | 1 | | | | | | | | | | | | 1 |
| | Cooling Towers | | | 1 | 1 | | | | | | | | | 2 |
| Retrofit Efficiency Options Program Total | | 2 | | 1 | 1 | | | | | | | | | 4 |
| APO | Water Chillers | 5 | | | | | | 2 | | | | | | 7 |
| | Customized EMS | | | 1 | | | | | | | 1 | | | 2 |
| | Customized Controls | 3 | | | | | | 1 | | | | | | 4 |
| | Other Customized Equip | 1 | | 2 | | | | | | | | | | 3 |
| | Other HVAC Technologies | 1 | | | | | | | | | | 1 | | 2 |
| Advanced Performance Options Program Total | | 10 | | 3 | | | | 3 | | | 1 | 1 | | 18 |
| **Total** | | 33 | 1 | 5 | 5 | 1 | 4 | 8 | 5 | 0 | 5 | 9 | 0 | 76 |

*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** | 147 | 73 | 6 | 55 | 32 | 30 | 37 | 44 | 32 | 34 | 63 | 36 | **589** |

### *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 1998 actually installed measures in 1997, or 1998.

#### 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.

The project completion date variable in the MDSS is designated as the installation date. The project completion date is populated 99 percent of the time and falls between the pre- and post-installation inspection dates. When the project completion date is missing, the paid date and the post-installation date are used to derive an installation date. 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.

#### 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 1998. To maximize the number of post installation months in the regression model, a post period of October 1998 through September 1999 was used. As illustrated in Exhibit 3-17, this post period occurs after 95 percent of the installation dates.

Based on the selection of post period, the period from October 1996 through September 1997 was used as the pre-period. Exhibit 3-17 suggests that almost every installation occurred between January 1997 and December 1997.

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 3-18 provides the cumulative participation by month for the participants that are part of the billing analysis sample frame.

### *3.3.5 Data Censoring*

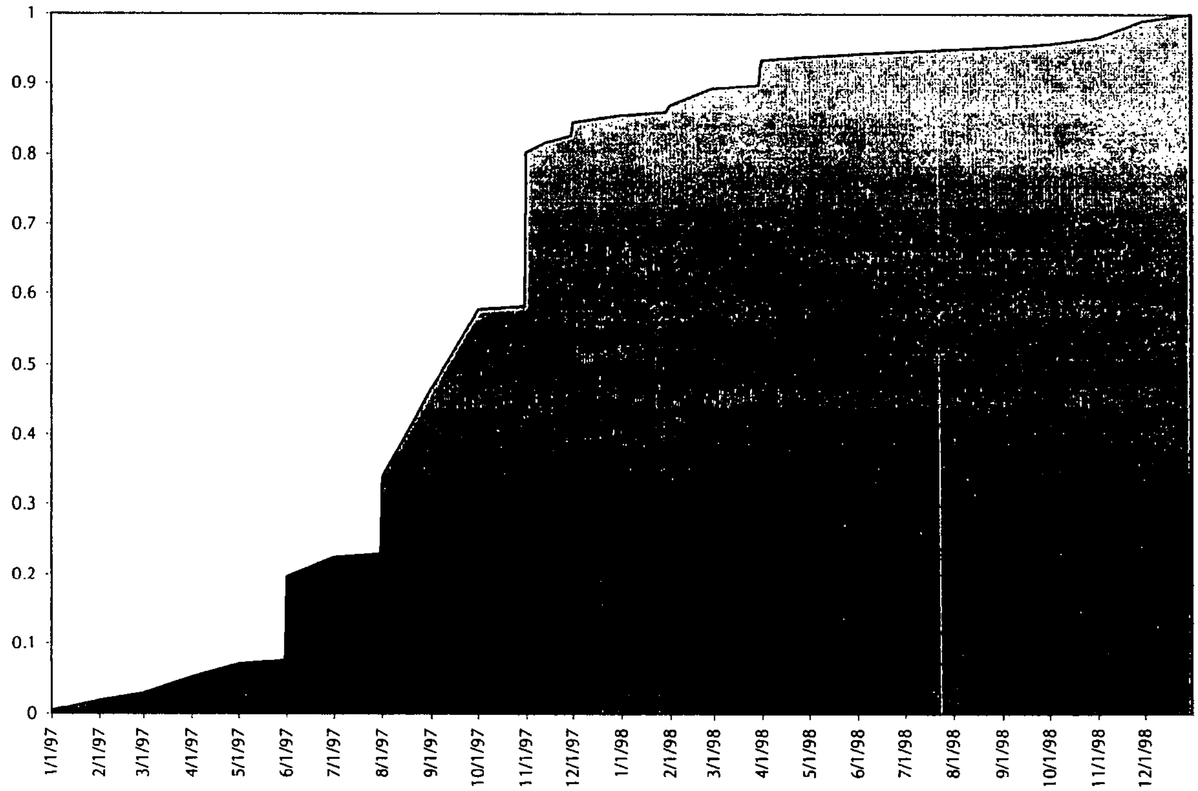
Three types of data censoring screens were applied to the billing analysis sample frame to remove customers: those that had invalid billing data, those that may not have had their bill properly aggregated to the Site ID level, or those that were extremely large users.

#### Invalid Usage

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

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

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




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

Finally, customers were removed from the analysis if they had a measure installed under the program that would result in an increase in usage. These individuals were identified through customer interviews.

Exhibit 3-18 presents the number of participants and nonparticipants that were deleted for each of the above criteria. Note that only 14 nonparticipants were deleted, whereas 28 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 drawn as a census and no pre-screening was done on their billing data prior to being selected into the participant survey sample frame. Of the 28 participants, 18 were deleted due to the zero bill criteria.

### 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. There were 15 participants that were identified as having total Commercial Sector Program energy impacts that were greater than their pre-installation, and were dropped from the analysis. The large majority of these customers were also found to have invalid usage.

### Large Customers

Customers whose annual pre-installation energy consumption exceeded three million kWh were excluded from the billing analysis. A total of 40 participants and 58 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 previous three Lighting Evaluations, all of which were unsuccessful in obtaining reliable results when including customers with usage above this level. This is also consistent with the recommendations made by the Verification Reports of PG&E's 1995 through 1997 Commercial Lighting Evaluations, which stated in 1995 that "program effects can be difficult to detect for large customers," and recommended censoring large customers for 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.

***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 >= 4 | Usage Tripled or Cut by a Third | Measure Caused Increase in Usage | Number Removed From Analysis |
|---|---|---|---|---|
| NP | NO | YES | NO | 2 |
| NP | YES | NO | NO | 9 |
| NP | YES | YES | NO | 3 |
| TOTAL | | | | 14 |
| P | NO | NO | YES | 6 |
| P | NO | YES | NO | 4 |
| P | YES | NO | NO | 9 |
| P | YES | YES | NO | 9 |
| TOTAL | | | | 28 |

In summary, out of the original sample frame of 589 nonparticipants, 71 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 255 HVAC and lighting participants, 70 were removed because of bad billing, improper site aggregation, or because they were large customers. Of these 70 customers, 23 were lighting participants.

Exhibit 3-19 summarizes the total number of participants and nonparticipants that were removed from the billing analysis. Exhibits 3-20 and 3-21 present the final sample sizes used in the billing analysis by business type and technology for participants and by business type for nonparticipants.

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

| Participant or Nonparticipant | Zero Monthly Bills >= 4 | Usage Tripled or Cut by a Third | Measure Caused Increase in Usage | Large Customer | Bill Not Aggregated Properly | Number Removed From Analysis |
|---|---|---|---|---|---|---|
| NP | NO | NO | NO | NO | NO | 57 |
| NP | NO | NO | NO | NO | NO | 1 |
| NP | NO | NO | NO | NO | NO | 1 |
| NP | NO | NO | NO | NO | NO | 9 |
| NP | NO | NO | NO | NO | NO | 3 |
| Total Nonparticipants | | | | | | 71 |
| NP | NO | NO | NO | NO | NO | 5 |
| NP | NO | NO | NO | NO | NO | 37 |
| NP | NO | NO | NO | NO | NO | 6 |
| NP | NO | NO | NO | NO | NO | 3 |
| NP | NO | NO | NO | NO | NO | 1 |
| NP | NO | NO | NO | NO | NO | 4 |
| NP | NO | NO | NO | NO | NO | 3 |
| NP | NO | NO | NO | NO | NO | 2 |
| NP | NO | NO | NO | NO | NO | 2 |
| NP | NO | NO | NO | NO | NO | 6 |
| NP | NO | NO | NO | NO | NO | 1 |
| Total Participants | | | | | | 70 |
| Total HVAC Participants | | | | | | 23 |

*Exhibit 3-20*
***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 | 8 | 1 | 1 | 2 | | 3 | 2 | 1 | | 3 | 4 | | 25 |
| | Adjustable Speed Drives | 2 | | | | | | | | | | | | 2 |
| | Package Terminal A/C | 1 | | | 1 | | | | 4 | | | | | 6 |
| | Set-Back Thermostat | | | | | | | | | | | 1 | | 1 |
| | Reflective Window Film | 5 | | | | | | | | | | 1 | | 6 |
| | Water Chillers | | | | | | | | | | | 1 | | 1 |
| | Other HVAC Technologies | | | | | 1 | | | | | | | | 1 |
| Retrofit Express Program Total | | 16 | 1 | 1 | 3 | 1 | 3 | 2 | 5 | 0 | 3 | 7 | 0 | 42 |
| REO | Adjustable Speed Drives | | | | | | | | | | | | | |
| | Water Chillers | 1 | | | | | | | | | | | | 1 |
| | Cooling Towers | | | | 1 | | | | | | | | | 1 |
| Retrofit Efficiency Options Program Total | | 1 | | | 1 | | | | | | | | | 2 |
| APO | Water Chillers | | | | | | | | | | | | | |
| | Customized EMS | | | | | | | | | | | | | |
| | Customized Controls | 2 | | | | | | 1 | | | | | | 3 |
| | Other Customized Equip | | | | | | | | | | | | | |
| | Other HVAC Technologies | | | | | | | | | | | | | |
| Advanced Performance Options Program Total | | 2 | | | | | | 1 | | | | | | 3 |
| **Total** | | 19 | 1 | 1 | 4 | 1 | 3 | 3 | 5 | 0 | 3 | 7 | 0 | 47 |

*Exhibit 3-21*
***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** | 122 | 71 | 4 | 51 | 30 | 30 | 30 | 37 | 29 | 29 | 54 | 31 | 518 |

### *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:

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

Where,

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

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

$NChg_{i,k}$ are the nonparticipant 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 and in facility square footage;

$\beta$, $\gamma$ and $\eta$ are the estimated slopes on their respective independent variables. Separate slopes on pre-usage are estimated by business type; and,

$\varepsilon$ is the random error term of the model.

For each customer in the analysis dataset (participants and nonparticipants), a post-installation predicted usage value is calculated using the parameters of the baseline models estimated for the 1997 to 1999 analysis period. They both take the same functional form with different segment-level intercept series and slopes ($\beta$ and $\gamma$):

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

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 ( $NChg_{i,k}$ ), were not included in the estimate post-installation predicted usage. The SAE model discussed below did include the participant and nonparticipant self-reported change variables to control for the differences between actual and predicted post-installation usage.

This issue was a major point of contention during the verification study of the 1996 CEEI Evaluation. The recommendation made by the verification study was to include the change variables in the estimation of the post-installation predicted usage. However, the Independent Reviewers agreed with PG&E that these change variables should not be included in the post-installation predicted usage.

PG&E and Quantum Consulting, who has acted as PG&E's evaluation contractor for the past four years, met with the ORA's verification contractor, ECONorthwest, to discuss this issue in more detail. ECONorthwest agreed that applying the nonparticipant parameters for the change variables to the participants was not correct for the reasons described above. However, ECONorthwest raised an additional concern regarding the lack of inclusion of nonparticipants in the second stage SAE Model. ECONorthwest suggested the use of a switching regression[10] to address their concerns with the inclusion of the nonparticipants. PG&E and Quantum Consulting researched this approach and successfully implemented the technique in last year's Evaluation. The switching regression technique is again adopted for this year's analysis

Exhibit 3-22 summarizes the final baseline model results that were estimated using 518 nonparticipant customers, as discussed in the *Data Censoring* section. Exhibit 3-22 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 (1997 to 1999):

[10] For a fuller explanation of switching regressions refer to:

Green, W., "Econometric Analysis," Macmillan Publishing Company, NY, 1990, pp. 748-750.

Maddala, G. S., "Limited-Dependent and Qualitative Variables in Econometrics," Cambridge University Press, Cambridge, 1987, pp. 283-290.

$$\hat{kWh}_{99,i} = 0.86 * OFFICE7 + 0.88 * RETAIL7 + 0.93 * SCHOOL7 + 1.02 * COLLEGE7 + 0.88 * GROCERY7 + 0.78 * RESTRNT7 + 0.90 * HOSP7 + 0.92 * HOTMOT7 + 0.80 * WHRSE7 + 0.86 * PERSVC7 + 0.86 * COMMUN7 + 0.98 * MISC7 - 0.000273 * CDD1\_97_{99-97,i} * kWh_{97,i} - 0.000097 * CDD11\_97_{99-97,i} * kWh_{97,i}$$

***Exhibit 3-22***
***Billing Regression Analysis Final Baseline Model Outputs***

| Parameter Descriptions | Analysis Variable Name | Units | Parameter Estimate | t-Statistic | Sample Size |
|---|---|---|---|---|---|
| **Pre-Usage** | | | | | |
| Office | OFFICE7 | kWh | 0.864184 | 31.75 | 122 |
| Retail | RETAIL7 | kWh | 0.875604 | 25.99 | 71 |
| School | SCHOOL7 | kWh | 0.927060 | 27.91 | 51 |
| College | COLLEGE7 | kWh | 1.015876 | 14.36 | 4 |
| Grocery | GROCERY7 | kWh | 0.884046 | 25.38 | 30 |
| Restaurant | RESTRNT7 | kWh | 0.782524 | 21.42 | 30 |
| Hospital | HOSP7 | kWh | 0.903020 | 25.84 | 30 |
| Hotel/Motel | HOTMOT7 | kWh | 0.917125 | 30.48 | 37 |
| Warehouse | WHRSE7 | kWh | 0.789896 | 20.74 | 29 |
| Personal Service | PERSVC7 | kWh | 0.855987 | 11.40 | 29 |
| Comm. Servcie | COMMUN7 | kWh | 0.858758 | 17.41 | 54 |
| Miscellaneous | MISC7 | kWh | 0.978857 | 13.37 | 31 |
| **Weather Changes** | | | | | |
| Change in CDD CliZone 1,2,3,4,5 | CDD1_97 | CDD*kWh | -0.000273 | -4.61 | 232 |
| Change in CDD CliZone 11,12,13,16 | CDD11_97 | CDD*kWh | -0.000097 | -2.88 | 286 |
| **Other Site Changes** | | | | | |
| Lighting Changes | LGT_CHG7 | kWh | 0.100211 | 5.14 | 60 |
| HVAC Changes | AC__CHG7 | kWh | 0.008429 | 0.49 | 71 |
| Other Equipment Changes | OTH_CHG7 | kWh | -0.035692 | -1.53 | 42 |
| Square Footage Changes | SQFT_CH7 | # Sqft*kWh | -1.012276 | -1.50 | 20 |
| Employee Changes | EMP_CHG7 | # Emp*kWh | 332.980301 | 3.16 | 413 |
| EMS Changes | EMS_CHG7 | kWh | -0.024088 | -1.86 | 82 |

## 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:

$$kWh_{99,i} - \hat{kWh}_{99,i} = kWh_{99,i} - F_{97}(kWh_{97}, \Delta CDD) = \sum_m \beta'_m Eng_m + \sum_k \rho'_k PChg_{i,k} + \sum_k \eta'_k NChg_{i,k} + \mu_i$$

Where,

$kWh_{99,i}$ and $kWh_{97,i}$ are customer i's annualized energy usage for the post- and pre-installation periods, respectively;

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

$\beta'_m Eng_m$ are the participant engineering impacts;

$PChg_{i,k}$ are the participant 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 and in facility square footage;

$NChg_{i,k}$ are the nonparticipant 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 and in facility square footage;

The difference between predicted and actual usage in 1999 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 1999 usage as a function of 1997 usage and change of cooling degree days from 1997 to 1999. 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 3-23 summarizes the final SAE model results that were estimated using 703 customers (185 participants and 518 nonparticipants), 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.

The dependent variable is the difference between the actual and predicted 1999 usage using the 1997 baseline model.

SAE coefficients are calculated for seven 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.

*Exhibit 3-23*
*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 | LGTOFF7 | kWh | -0.824743 | -3.05 | 50 |
| Lighting Retails | LGTRET7 | kWh | -0.891237 | -1.32 | 23 |
| Lighting Schools | LGTSCH7 | kWh | -0.779395 | -1.01 | 14 |
| Lighting Miscellaneous | LGTMSC7 | kWh | -0.596705 | -1.34 | 56 |
| **HVAC End Use** | | | | | |
| Retrofit Express Measures | RETXHVC | kWh | -1.150815 | -1.38 | 42 |
| Custom HVAC | CUSTHVC | kWh | -0.757689 | -1.36 | 6 |
| **Other End Uses** | | | | | |
| Other Impacts | OTHMEAS7 | kWh | 0.100398 | 0.05 | 18 |
| **Change Variables** | | | | | |
| Part Lighting Changes | LGT_CHG7 | kWh | -0.019670 | -0.72 | 18 |
| Part HVAC Changes | AC__CHG7 | kWh | -0.064773 | -2.53 | 28 |
| Part Other Equipment Changes | OTH_CHG7 | kWh | -0.025256 | -0.38 | 4 |
| Part Square Footage Changes | SQFT_CH7 | # Sqft*kWh | 11.647230 | 4.79 | 6 |
| Part Employee Changes | EMP_CHG7 | # Emp*kWh | 611.527341 | 1.27 | 27 |
| Part EMS Changes | EMS_CHG7 | kWh | 0.049254 | 2.64 | 38 |
| Nonpart Lighting Changes | LGT_NON7 | kWh | 0.100211 | 5.94 | 60 |
| Nonpart HVAC Changes | AC__NON7 | kWh | 0.008429 | 0.60 | 71 |
| Nonpart Other Equipment Changes | OTH_NON7 | kWh | -0.035692 | -1.86 | 42 |
| Nonpart Square Footage Changes | SQFT_NO7 | # Sqft*kWh | -1.012276 | -1.60 | 20 |
| Nonpart Employee Changes | EMP_NON7 | # Emp*kWh | 332.980301 | 3.38 | 598 |
| Nonpart EMS Changes | EMS_NON7 | kWh | -0.024088 | -2.54 | 82 |

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 two distinct technology groupings: RE measures, and Custom measures. The 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.

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, as well as changes made to the size (square footage) of the building and with the number of employees. Separate change variables were developed for participants and nonparticipants for the reasons discussed above. The final SAE coefficients for the HVAC end use is provided in Exhibit 3-24. The SAE coefficient is multiplied by the evaluation estimates of gross energy impact to calculate the gross ex post energy impacts.

***Exhibit 3-24***
***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 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 |
| | Adjustable Speed Drives | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 |
| | Package Terminal A/C | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 |
| | Set-Back Thermostat | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 |
| | Reflective Window Film | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 |
| | Water Chillers | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 |
| | Other HVAC Technologies | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 |
| Retrofit Express Program Total | | | | | | | | | | | | | |
| REO | Adjustable Speed Drives | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 |
| | Water Chillers | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 |
| | Cooling Towers | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 |
| | High Efficiency Gas Boilers | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 |
| Retrofit Efficiency Options Program Total | | | | | | | | | | | | | |
| APO | Water Chillers | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 |
| | Customized EMS | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 |
| | Customized Controls | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 |
| | Convert To VAV | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 |
| | Other Customized Equip | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 |
| | Other HVAC Technologies | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 |

## 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 three analysis segments that were explicitly modeled, and the relative precision estimates based upon the model output are presented in Exhibit 3-25 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 $\beta_i$ 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]

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

Where,

$CV_i = \dfrac{std(\beta_i)}{\beta_i}$ 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 3-25 presents the relative precision calculations.

*Exhibit 3-25*
*Relative Precision Calculation*

| SAE Analysis Level | Gross Engineering Energy Impact (kWh) | SAE Coefficient | t-Statistic | Relative Precision at 80% | Relative Precision at 90% |
|---|---|---|---|---|---|
| **HVAC End Use** | | | | | |
| Retrofit Express Measures | 4,086,548 | -1.15 | 1.38 | 93% | 119% |
| Custom HVAC | 16,590,710 | -0.76 | 1.36 | 94% | 121% |
| HVAC Total | 20,677,258 | -0.84 | 1.75 | 73% | 94% |

[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. As with the gross billing model, the net billing model specification also 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. 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. Including an Inverse Mills Ratio in the model as an explanatory variable controls for the influence of the characteristics that cause participants to self-select into the retrofit program. 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) developed 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. A description of how the Inverse Mills Ratio is used in the Net Billing Model is also discussed, along with the estimation results from the Net Billing Model. Finally, a presentation of alternative model specifications is provided.

### 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 received a rebate in 1998 for participating in a CEEI HVAC Program and a zero otherwise. The sample includes 76 HVAC Program participants and 5,101 HVAC 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 but 6 of the 5,177 survey respondents were used to estimate the participation probit for the HVAC Program[14].

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

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

A description of the explanatory variables is given in Exhibit 3-26. The dependent variable PARTICIPATION has a value of one if the customer received a rebate in 1998 for participating in a CEEI 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 indicate whether a respondent was aware of the CEEI HVAC program prior to 1998. There are three of these variables. The first is AWARE, which takes a value of one if a respondent indicates awareness. The second and third awareness variables will take a value of one if the respondent is aware prior to 1998, **and** claims to have been informed of the program by their HVAC contractor (HV_INFO) or their PG&E representative (PGE_INFO). Including these variables allows the model to differentiate between respondents who simply claim they were aware, and those who also state the source of their information. The latter group are likely to have more complete and accurate information about the program, and therefore will be affected in a different way by their awareness. Moreover, these variables are intended to assuage concerns evaluaters commonly have regarding the dependability of self-reported awareness.

The second group of variables (Y) reflect the building characteristics. Examples of these include ownership, recent changes at the facility, as well as total energy use. The third group of

[14] These 34 respondents were excluded due to incomplete billing data, which was necessary for constructing one of the independent variables (USE) in the probit regression model.

variables (Z) contain information on business type. Finally, the error term ($\varepsilon$) is assumed to be normally distributed for the probit specification.

### Probit Estimation Results

The estimation results for the HVAC probit are given in Exhibit 3-27. The results are generally supportive of a priori expectations. The HVAC probit results indicate customers who were aware of the program prior to 1998 are more likely to participate in the HVAC program. Further, those who were aware of the program prior to 1998 and received program information from their HVAC contractor or their PG&E representative are also more likely to participate. Size (as indicated by energy use) ownership, and tenant activity all showed a positive effect on the probability of participation. Most of the change variables also showed an increase in the probability of participation. Additionally, those in facilities built before 1978 are more likely to participate. These results all conform to expectations. However, the addition and removal of heating equipment (ARHEAT) produced a negative coefficient, contrary to expectations. Our results show that awareness, building age, and size, as indicated by energy use, are very strong predictors of participation in the HVAC program, while the effect of other factors is less easily understood.

*Exhibit 3-26*
*Variables Used in HVAC Probit Model*

| Variable Name | Units | Variable Type | Description |
|---|---|---|---|
| AWARE | 0,1 | X | Aware of Program Prior to 1998 |
| ARLIGHT | 0,1 | Y | Lighting equipment was added and removed since 1/97 |
| ARHEAT | 0,1 | Y | Heating equipment was added and removed since 1/97 |
| B4_78 | 0,1 | Y | Building was constructed before 1978 |
| EMPCHG | 0,1 | Y | Employee change by 10% since 1/97 |
| GROCERY | 0,1 | Z | Grocery |
| HEALTH | 0,1 | Z | Health Care Building |
| HOTEL | 0,1 | Z | Hotel |
| HV_INFO | 0,1 | X | Made aware by HVAC contractor prior to 1998 |
| MISCCOM | 0,1 | Z | Miscellaneous commercial building |
| OFFICE | 0,1 | Z | Office building |
| OWN | 0,1 | Y | Own building |
| PERSONL | 0,1 | Z | Personal services building |
| PGE_INFO | 0,1 | X | Made aware by PG&E representative prior to 1998 |
| RESTR | 0,1 | Z | Restaurant |
| RETAIL | 0,1 | Z | Retail building |
| SCHOOL | 0,1 | Z | School |
| SFADD | 0,1 | Y | Square footage added to the facility |
| SHTLEASE | 0,1 | Y | Lease less than 1 year long |
| USE | kWh | Y | Energy use in 1997 |
| TENACT | 0,1 | Y | Tenants active in equipment purchse decisions |
| WARE | 0,1 | Z | 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,

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

*Exhibit 3-27*
***HVAC Probit Estimation Results***

| Variable Name | Units | Variable Type | Coefficient Estimate | Standard Error | Significance Level |
|---|---|---|---|---|---|
| INTERCEPT | NA | NA | -3.14 | 0.26 | 1% |
| AWARE | 0,1 | X | 0.66 | 0.18 | 1% |
| ARLIGHT | 0,1 | Y | 0.20 | 0.16 | 20% |
| ARHEAT | 0,1 | Y | -0.31 | 0.23 | 17% |
| B4_78 | 0,1 | Y | 0.49 | 0.14 | 1% |
| EMPCHG | 0,1 | Y | 0.25 | 0.16 | 10% |
| GROCERY | 0,1 | Z | -0.62 | 0.44 | 16% |
| HEALTH | 0,1 | Z | 0.00 | 0.23 | 99% |
| HOTEL | 0,1 | Z | 0.10 | 0.28 | 71% |
| HV_INFO | 0,1 | X | 0.17 | 0.91 | 34% |
| MISCCOM | 0,1 | Z | -5.65 | 8209.42 | 99% |
| OFFICE | 0,1 | Z | 0.14 | 0.17 | 41% |
| OWN | 0,1 | Y | 0.81 | 0.23 | 1% |
| PERSONL | 0,1 | Z | -0.19 | 0.25 | 43% |
| PGE_INFO | 0,1 | X | 0.08 | 0.18 | 64% |
| RESTR | 0,1 | Z | -0.24 | 0.26 | 37% |
| RETAIL | 0,1 | Z | -0.90 | 0.37 | 2% |
| SCHOOL | 0,1 | Z | -0.11 | 0.27 | 68% |
| SFADD | 0,1 | Y | 0.12 | 0.23 | 59% |
| SHTLEASE | 0,1 | Y | -0.34 | 0.44 | 44% |
| USE | kWh | Y | 4.72E-07 | 1.59E-07 | 1% |
| TENACT | 0,1 | Y | 0.49 | 0.27 | 7% |
| WARE | 0,1 | Z | -5.75 | 10754.55 | 99% |

The function $\phi$ is the standard normal probability density function and $\Phi$ 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.

### 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 two 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:

- 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:

$$
\begin{aligned}
kWh_{99,i} - k\hat{W}h_{99,i} &= kWh_{99,i} - F_{97}(kWh_{97,i}, \Delta CDD_i) \\
&= \vartheta_1 Mills_{Light,i} + \vartheta_2 Mills_{HVAC,i} + \sum_m \delta_m Mills_{Light,i} * Eng_{Light,m,i} \\
&\quad + \sum_m \delta_m Mills_{HVAC,i} * Eng_{HVAC,m,i} + \sum_k \eta_k' NChg_{i,k} + \sum_k \rho_k' PChg_{i,k} + \varepsilon
\end{aligned}
$$

Where

$kWh_{99,i}$ and $kWh_{97,i}$ are customer i's annualized energy usage for the post- and pre-installation periods, respectively;

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

$NChg_{i,k}$ are the nonparticipant 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;

$PChg_{i,k}$ are the participant 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;

$\vartheta$ and $\delta$ are the coefficients on the individual Mills ratios, and on the Mills ratios interacted with the engineering energy impacts, respectively;

$\varepsilon$ is the random error term of the model.

This net SAE model was run with the same set of 518 nonparticipants and 185 participants that were used in the gross billing analysis model. The results of the model are presented in Exhibit 3-28. The parameter estimates, t-statistics and sample sizes are presented for all of the net SAE coefficients and Mills ratios..

***Exhibit 3-28***
***Net Billing Regression Analysis Final Model Outputs***

| Parameter Descriptions | Analysis Variable Name | Units | Parameter Estimate | t-Statistic | Sample Size |
|---|---|---|---|---|---|
| **Mills Ratios** | | | | | |
| Lighting | LRMILLS | Unitless | 7309.376033 | 1.19 | 703 |
| HVAC | HRMILLS | Unitless | 2565.422514 | 0.29 | 703 |
| **SAE Coefficients** | | | | | |
| **Lighting End Use** | | | | | |
| Lighting Offices | LGTOFFM | Mills * kWh | -0.465558 | -2.89 | 50 |
| Lighting Retails | LGTRETM | Mills * kWh | -0.662977 | -1.25 | 23 |
| Lighting Schools | LGTSCHM | Mills * kWh | -0.600164 | -0.90 | 14 |
| Lighting Miscellaneous | LGTMSCM | Mills * kWh | -0.450717 | -1.85 | 56 |
| **HVAC End Use** | | | | | |
| Retrofit Express Measures | RETXHVM | Mills * kWh | -0.600785 | -1.15 | 42 |
| Custom HVAC | CUSTHVM | Mills * kWh | -0.45317 | -1.25 | 6 |
| **Change Variables** | | | | | |
| Part Lighting Changes | LGT_CHG7 | kWh | -0.021378 | -0.78 | 18 |
| Part HVAC Changes | AC__CHG7 | kWh | -0.067164 | -2.57 | 28 |
| Part Other Equipment Changes | OTH_CHG7 | kWh | -0.055311 | -0.88 | 4 |
| Part Square Footage Changes | SQFT_CH7 | # Sqft*kWh | 11.673152 | 4.75 | 6 |
| Part Employee Changes | EMP_CHG7 | # Emp*kWh | 567.081509 | 1.17 | 27 |
| Part EMS Changes | EMS_CHG7 | kWh | 0.045470 | 2.42 | 38 |
| Nonpart Lighting Changes | LGT_NON7 | kWh | 0.100325 | 5.93 | 60 |
| Nonpart HVAC Changes | AC__NON7 | kWh | 0.009045 | 0.64 | 71 |
| Nonpart Other Equipment Chan | OTH_NON7 | kWh | -0.035328 | -1.84 | 42 |
| Nonpart Square Footage Chang | SQFT_NO7 | # Sqft*kWh | -0.998534 | -1.58 | 20 |
| Nonpart Employee Changes | EMP_NON7 | # Emp*kWh | 335.619754 | 3.40 | 598 |
| Nonpart EMS Changes | EMS_NON7 | kWh | -0.023125 | -2.42 | 82 |

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:

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

Where,

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

$\beta_m$ is the SAE coefficient from the Gross Billing model for technology m; and,

$\delta_m$ is the regression coefficient from the Mills Model 1 regression for technology m.

Exhibit 3-29 illustrates the resulting estimate of net, or one minus free-ridership.

***Exhibit 3-29***
***Net Billing Regression Analysis Estimates of (1-FR)***

| | Mills Model 1 | | Gross Model | | From Probit | |
|---|---|---|---|---|---|---|
| **Parameter Descriptions** | **Variable Name** | **Parameter Estimate** | **Variable Name** | **Parameter Estimate** | **Mean Mills** | **Resulting (1-FR)** |
| **SAE Coefficients** | | | | | | |
| **HVAC End Use** | | | | | | |
| Retrofit Express Measures | RETXHVM | -0.601 | RETXHVC | -1.151 | 1.029 | 0.537 |
| Custom HVAC | CUSTHVM | -0.453 | CUSTHVC | -0.758 | 0.915 | 0.547 |

## 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 post 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 self-reported survey data are presented. This is followed by a discussion of 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 255 HVAC and lighting participant surveys, 589 nonparticipant surveys and 4,333 canvass telephone surveys collected in 1999. Other data used in this analysis include the MDSS and CIS databases, and information from the Advice Filings.

### *3.4.2 Self-report Methods*

On May 20, 1999 the CADMAC approved a waiver that allows the use of self -report based algorithms to estimate free ridership and spillover effects in the event discrete choice and LIRM models fail to produce statistically reliable results. The approved waiver is presented in Attachment 5.

#### 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.

Overview of Methodology

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 comprehensive 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 HVAC 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...*<br><br>1 = We would not have changed our HVAC system<br>2 = We would have bought high-efficiency HVAC equipment<br>3 = We would have bought standard efficiency HVAC<br>8 = (Refused)<br>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...*<br><br>1 = We would have installed high efficiency HVAC at the same time we did it through the program<br>2 = We would have installed high efficiency HVAC within the year<br>3 = We would have installed high efficiency HVAC, but not within the year<br>4 = We wouldn't have installed high efficiency HVAC at all<br>8 = (Refused)<br>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 = 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 condition, the respondent 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.

In the event the participant was unable to answer question pd310, or provided contradictory answers to pd310 and pd315, the data was considered inconclusive. Specifically, data was considered inconclusive if:

**pd310 = 2 AND pd315=4**

**pd310=2 AND pd315=Refused/Don't Know**

**pd310 = Refused/Don't Know**

Under the first condition the respondent indicated that in the absence of the program, they would have purchased high efficiency equipment. However, when the respondent was asked when they would have purchased this equipment, they stated that they would not have installed high efficiency HVAC equipment at all. Under the second condition the participant answered "don't know" or refused to give a response to question pd310. If either of these conditions applied, a second set of questions was examined to determine free ridership:

| | |
|---|---|
| **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).*<br><br>1 = You hadn't even considered purchasing new HVAC equipment.<br>2 = You were interested in installing HVAC equipment, but hadn't yet decided on energy efficient HVAC equipment. (i.e. you were considering all your options.)<br>3 = You had already decided to install HIGH efficiency HVAC, but probably not within the year.<br>4 = You had already decided to install HIGH efficiency HVAC within the year.<br>8 = (Refused)<br>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 they knew about the program, they had already decided to install high efficiency equipment within the year.

The respondent's answer to pd300 was considered inconclusive if:

| |
|---|
| **pd300 = 2** |
| **pd300=Refused/Don't Know** |

Under the first condition the respondent has not clearly indicated what their behavior would be in the absence of the program. Under the second condition, the respondent answered a "don't know" or refused to give an answer to question pd300. If either of these conditions held, a third survey question was used to determine free ridership:

| | |
|---|---|
| **pd250** | *If you had not replaced this equipment under the program how long would you have waited to replace it?*<br><br>1 = You would have replaced the equipment at the same time<br>2 = You would have replaced the equipment at a year or within a year<br>3 = You would have replaced the equipment more than a year later<br>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 was not 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 within one year, were counted as free riders.

If the initial combination of questions (pd310 and pd315), could not classify a response because of contradictory, or "don't know" or "refusal" responses, then the responses to the additional questions were used. Question pd300 made almost the same distinctions as the initial 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 255 completed telephone surveys of CEEI program participants. The responses included 76 HVAC end use adopters. The surveys were conducted between April and August of 1999 as part of a comprehensive telephone survey of CEEI program participants.

HVAC Results

Self-reported estimates of free ridership are presented in Exhibit 3-30 below by technology group. Package Terminals and Other Custom had the lowest rates of free ridership, 10 and 24 percent respectively. There was a only one surveyed participant who had adopted an Evaporative Cooler, and this participant was a free rider. Higher rates of free ridership were also observed in the Reflective Window Film and Central Air Conditioning categories, 55% and 78% respectively. These free ridership rates were developed within technology group by weighting by each site's avoided cost associated with the technology retrofit.

*Exhibit 3-30*
*Weighted Self-report Estimates of Free Ridership for HVAC Technology Groups*

| Technology Group | Sample | Free Ridership |
|---|---|---|
| Adjustable Speed Drives | 7 | 40.7% |
| Central Air Conditioning | 31 | 55.2% |
| Evaporative Cooler | 1 | 100.0% |
| Other Custom Measures | 22 | 23.8% |
| Package Terminals | 6 | 10.4% |
| Set Back Thermostats | 8 | 44.0% |
| Reflective Window Film | 11 | 78.0% |
| Total - Weighted by Avoided Cost | 86 | 25.5% |

## 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 the rate at which the participant or nonparticipant population is adopting non-rebated high-efficiency HVAC equipment as a result of being influenced by the CEEI program. 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 non-rebated high-efficiency adoptions occurring in the participant or nonparticipant population as a result of CEEI program influence.

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 ratio of the number of spillover adoptions to the total surveyed population. Thus, the spillover rate reflects the rate at which the participant or nonparticipant population is making non-rebated, high-efficiency HVAC equipment adoptions as a result of CEEI program influence.

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

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

2. the respondent was **aware** of the program **before** making the decision to purchase new HVAC equipment

3. the adoption was **not rebated** as part of the program

4. the respondent stated that the adoption occurred 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 that meet the spillover criteria, the spillover rate was calculated by dividing the total number of spillover adoptions by 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. For HVAC equipment that might be either high efficiency or standard efficiency, question cr117 was used to determine the efficiency of the additional technology. If an HVAC response qualified as a spillover, it was checked against question cr117 to ensure that it was a high efficiency installation. The text for these questions were as follows:

| | |
|---|---|
| **cr020** | *Since January 1997, did you add to, replace, or remove any cooling equipment?* |
| **cr099** | *What type of units were added?* |
| **cr117** | *Is the additional technology standard efficiency or did you have to pay extra for a high efficiency unit?* |

**For Condition 2:**

Question cr050 and sp160 were used to verify that the out-of-program HVAC adoption occurred after the respondent became aware of the Retrofit Program. The question text is as follows:

| | |
|---|---|
| **Cr050** | *Were these changes made after you participated in the Retrofit Program?* |
| **Sp160** | *Did you become aware of the Retrofit Program before or after you made the decision to purchase your new HVAC equipment?* |

**For Condition 3:**

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 4:**

The fourth condition, whether or not the program influenced the respondent's equipment selection, was tested with question sp110. Only those respondents who installed non-rebated HVAC equipment after they had become aware of the program were asked the final spillover question. Respondents who answered this question but installed standard efficiency equipment types were not counted as spillover. Because of this design, spillover could be calculated based on the response to question sp110 in conjunction with data on the efficiency of the installed HVAC equipment. The question text for sp110 was as follows:

| | |
|---|---|
| **sp110** | *How influential was the Retrofit Express Program in your selection of the additional equipment?*<br><br>1= Not at all influential<br>2= Slightly influential<br>3= Moderately influencial<br>4= Very influential<br>R= Refused<br>D=Don't know |

Participant Spillover Scoring Algorithm

The final scoring algorithm for participant spillover was based on question sp110, in conjunction with data on the efficiency of the installed HVAC equipment. This question was used because, as explained above, it was only asked of participants who made a **non-rebated** adoption **after** they had become aware of the program. The scoring algorithm is as follows:

| |
|---|
| **If sp110 = 2,3 or 4** |
| **AND equipment is high efficiency,** |
| **then spillover = 1** |

**else spillover = 0**

If a respondent scores a 1 for spillover, they have met all four 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.

Participant Self-report Spillover Results

Of the 255 HVAC and lighting participants surveyed, a total of 14 respondents met all of the spillover criteria excluding efficiency. Two of these 14 respondents installed standard efficiency equipment and 10 installed high efficiency equipment. The remaining 2 respondents had inconclusive data regarding efficiency. These 2 were divided between standard and high efficiency categories based upon the distribution of respondents who met all spillover criteria and had conclusive efficiency information. Thus 1.67 of the 2 remaining respondents were categorized as spillover actions. Finally, a total of 11.7 adoptions were identified as contributing to HVAC spillover. This results in a participant spillover rate of 4.6 percent. Because there were a total of 566 participants, this is equivalent to a total of 26 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. Also similarly, question cr117 was used to clarify the efficiency of the additional technology. 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:**

Questions is005 and sp160 were used to verify that the respondent was aware of the program before the HVAC technology was adopted. The text for these questions was as follows:

| | |
|---|---|
| **is005** | *Have you heard of PG&E's Retrofit Express programs?* |
| **sp160** | *Did you become aware of the Retrofit Express program before or after you made the decision to purchase your new HVAC equipment?* |

**For Condition 3:**

Question cr060 was used to determine whether or not the HVAC installation was 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 4:**

The fourth condition, whether or not the program influenced the respondent's equipment selection, was tested with question sp180. Only those respondents who were aware of the program before making the decision to purchase new HVAC equipment, and did not receive a rebate for this purchase were asked sp180. Respondents who answered this question but installed standard efficiency equipment were not counted as spillover. Because of this design, spillover could be calculated based on the response to question sp180, together with data on the efficiency of the installed HVAC equipment. The question text for sp180 was as follows:

| | |
|---|---|
| **sp180** | *Did your knowledge of the Retrofit Express program at all influence your additional HVAC equipment selection?*<br><br>1= Not at all influential<br>2= Slightly influential<br>3= Moderately Influential<br>4= Very Influential<br>R= Refused<br>D=Don't Know |

<u>Nonparticipant Spillover Scoring Algorithm</u>

The final scoring algorithm for nonparticipant spillover was based on question sp180, in conjunction with data on the efficiency of the installed HVAC equipment. Again, only respondents who stated that they were aware of the program before making the decision to purchase new HVAC equipment, and were not rebated for this purchase, were asked question sp180. Thus, the final spillover scoring algorithm was as follows:

**If sp180 = 2,3, or 4**

**AND equipment is high efficiency,**

**then spillover = 1,**

**else spillover = 0.**

If a respondent scores a 1 for spillover, they have met all four spillover conditions set forth above. The number of spillover adoptions resulting from this algorithm was divided by the number of nonparticipants surveyed to obtain the nonparticipant spillover rate.

Nonparticipant Self-report Spillover Results

Of the 4,923 nonparticipants surveyed, there were 6 respondents who met all of the spillover criteria excluding efficiency. Two of these 6 respondents installed standard efficiency equipment, and 4 installed high efficiency equipment. Therefore, a total of 4 respondents were identified as contributing to nonparticipant HVAC spillover.

Nonparticipants' reported HVAC adoptions spanned approximately a 30-month period (from January 1997 through approximately June 1999). In order to calculate the 1998 spillover rate, a constant adoption rate over the period was assumed. Thus, the portion of total adoptions captured in the survey assumed to occur in 1998 was calculated by dividing the 12 months in 1998 by the 30 months spanning the entire period, resulting in 40 percent.

The approach to distributing the spillover across the 30-month analysis period is conservative relative to alternative allocation methods. In the 1997 evaluation, we used the portion of all reported high efficiency HVAC adoptions occurring during program year 1997. If we were to use this method in the 1998 evaluation the resulting percent would be significantly higher, 49.7% versus 40.0%. A second alternative estimation method would be to mimic the distribution of all non-rebated HVAC adoptions, both standard and high efficiency. This method would also result in a measurably higher portion allocated to this year's evaluation, 51.5% versus 40%. As a third alternative, the portion of all HVAC adoptions, including rebated and non-rebated, high-efficiency and standard efficiency adoptions, occurring in 1998 could be used as an estimator. This portion is 50.5% and would also yield a higher spillover rate.

From PG&E's 1998 CIS, there were 416,496 unique sites identified, resulting in a total of 415,930 nonparticipant sites less the 566 participants. Therefore, because there were a total of 415,930 nonparticipants, the spillover rate of 0.04 percent is equivalent to a total of 168 nonparticipant spillover HVAC actions.

Calculation of Impacts Associated With Spillover

Self reported installation information and the MDSS database were used to calculate the impacts associated with spillover. 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 a spillover adoption could be calculated.

Participant Spillover Impact Calculation

About 12 participants were identified as contributing to spillover. Rather than using these 12 installations to calculate an average spillover impact, the survey sample of participant, out-of-program, high efficiency HVAC installations was used. There were a total of 22 high efficiency installations, for which valid responses were obtained for equipment type and number of units installed. These 22 installations were used to estimate the average participant 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 the average avoided cost per unit installed for each equipment type. When calculating average avoided cost per unit for water chiller and adjustable speed drives (ASDs), data from the REO and APOS programs was excluded. This was a conservative decision. Including data from the REO and APOS programs would have more than doubled the average avoided cost for both ASDs and increased it by more than 25-fold for water chillers.

The 22 participant out-of-program 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 yielded an estimate of the average avoided cost per participant installation by equipment type. The 22 participant installations were also used to determine the distribution of installations across equipment type. This method resulted in an average avoided cost per participant installation.

Exhibit 3-31 below, presents the average avoided cost per participant installation by equipment type, along with the distribution of installations across equipment type. The majority of participant adoptions were of single package A/C units, at 64% of total installations. The average avoided cost per participant was estimated at $5,974.

***Exhibit 3-31***
***Participant Out-of-Program Adoptions***

| Equipment Type | Ave # Units Per Prt Install | Per Unit Av Cost | Ave Av Cost Per Install | Distribution of Installs |
|---|---|---|---|---|
| Split System A/C | 2 | $1,648 | $3,956 | 22.7% |
| Single Package A/C | 3 | $1,648 | $4,121 | 63.6% |
| Water Chillers | 2 | $8,994 | $17,988 | 13.6% |
| Weighted Average *by Distribution of Installs* | | | $5,974 | |

Nonparticipant Spillover Impact Calculation

Four nonparticipants were identified as contributing to spillover. Rather than using these 4 installations to calculate an average spillover impact, the survey sample of non-rebated, out-of-program, high efficiency HVAC installations was used. There were a total of 224 high efficiency installations, for which valid responses were obtained for equipment type and number of units installed. These 224 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 the average avoided cost per unit installed for each equipment type. The 224 nonparticipant installations were used to determine the average number of units per installation by equipment type. Multiplying the number of units by the average avoided cost per unit from the MDSS yielded an estimate of the average avoided cost per nonparticipant installation by equipment type. The nonparticipant installations were also used to determine the distribution of installations across equipment type. This method resulted in an average avoided cost per nonparticipant installation.

Exhibit 3-32 below, presents the average avoided cost per nonparticipant installation by equipment type, along with the distribution of installations across equipment type. The average avoided cost per nonparticipant was estimated at $8,564.

***Exhibit 3-32***
***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 | 3 | $1,648 | $4,258 | 11.2% |
| Single Package A/C | 3 | $1,648 | $5,615 | 26.8% |
| Individual A/C | 3 | $1,648 | $4,820 | 25.9% |
| Package Terminal | 5 | $203 | $946 | 8.0% |
| Remote Condensing Unit | 1 | $8,809 | $8,809 | 2.2% |
| Evaporative Coolers | 4 | $2,242 | $7,998 | 13.8% |
| Water Chillers | 2 | $8,994 | $14,241 | 5.8% |
| Evaporative Condensers | 3 | $8,809 | $22,023 | 1.8% |
| Cooling Towers | 2 | $41,958 | $62,937 | 2.2% |
| EMS | 1 | $140,690 | $140,690 | 0.9% |
| Set Back | 7 | $816 | $5,712 | 1.3% |
| Weighted Average *by Distribution of Installs* | | | $8,564 | |

Calculating the Contribution of Spillover to the Total Net to Gross Ratio

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 $9,368,244 for the HVAC end use.

Participant Spillover NTG Calculation

Exhibit 3-33 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 1.65 percent.

***Exhibit 3-33***
***Participant Spillover Estimate***

| | |
|---|---|
| Avoided Cost Per Participant | $5,974 |
| Spillover Rate | 4.58% |
| Number of Participants | 566 |
| Number Contributing to Spillover | 26 |
| Spillover Avoided Cost | $154,707 |
| HVAC Avoided Cost | $9,368,244 |
| **NTG Contribution from ParticipantSpillover** | **1.65%** |

Nonparticipant Spillover NTG Calculation

Exhibit 3-34 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 12.36 percent.

*Exhibit 3-34*
*Nonparticipant Spillover Estimate*

| | |
|---|---|
| Avoided Cost Per Nonparticipant | $8,564 |
| Spillover Rate | 0.03% |
| Number of Nonparticipants | 415,930 |
| Number Contributing to Spillover | 135 |
| Spillover Avoided Cost | $1,157,715 |
| HVAC Avoided Cost | $9,368,244 |
| **NTG Contribution from Nonparticipant Spillover** | **12.36%** |

### *3.4.3 Discrete Choice Model*

As stated earlier, the number of HVAC program participants in 1998 was relatively small, at 137 unique sites. Of these, 76 completed telephone surveys. This sample is quite small relative to previous years. For example, the 1997 CEEI program had 1337 HVAC participants, of which 443 completed telephone surveys. The limited available sample significantly reduces the reliability of statistical modeling techniques.

Nevertheless, this section presents the results of a two-stage discrete choice model. This model is intended to simulate the decision to purchase commercial HVAC equipment. The results of this model may be 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.

In previous years the discrete choice analysis modeled the decision to purchase high and standard efficiency central air conditioners (CACs), as well as evaporative coolers. This year the data would not support a separate category for evaporative coolers. There was only 1 participant in the sample that had made an evaporative cooler adoption through the program. Therefore the following discrete choice analysis will model the decision to purchase high efficiency and standard efficiency CAC units only. This technology was selected because they comprised a large portion of the purchases made outside and inside the program and were judged to be reasonable substitute technologies. There were 31 participants who made CAC purchases through the program, and there were 74 nonparticipants that made CAC adoptions outside the program.

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 a CAC equipment purchase and is referred to as the **purchase probability**. The second stage of the model estimates the type of CAC 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 CAC 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 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 CAC 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 savings 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 purchase and nonpurchase groups. Those that purchased CAC equipment either inside 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 originally contained information on 2,960 customers. Of these, 934 were excluded because survey data indicated there was no air conditioning system at the site. The remaining 2,026 customers made a total of 261 CAC purchases. This is considerably fewer purchases than were found in the 1997 Evaluation data. The 1997 Evaluation purchase model included data on 2,155 customers that made 602 HVAC purchases. The reduction in purchases is explained by the smaller portion of participants in the 1998 Evaluation sample.

The 1998 sample contains 1,801 customers that are nonparticipants and did not make any HVAC equipment purchases. The other 226 customers purchased new CAC equipment between January 1997 and June of 1999. Of those that did make CAC equipment purchases, 31 customers made purchases within the HVAC Program. There were 96 customers that purchased high-efficiency CAC equipment outside the program. Finally, 109 customers reported purchasing standard CAC equipment. Some customers made more than one type of purchase.

### 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 a CAC equipment purchase either inside or outside the program and a zero if they did not purchase any CAC equipment. The purchase decision model specification is defined as:

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

Variable definitions are given in Exhibit 3-35. The explanatory variables X contain information on rebate and program awareness that capture the effect of the HVAC Program. Building characteristics such as square footage and changes to the facility are contained in Y. Variable group Z contains variables indicating building type. The error term ε is assumed to be distributed logistic consistent with the logit model specification

*Exhibit 3-35*
*Purchase Model Variable Definitions*

| Variable Name | Units | Variable Type | Description |
|---|---|---|---|
| AWARE | 0,1 | X | Aware of program prior to purchase |
| ARLIGHT | 0,1 | Y | Lighting equipment was added and removed since 1/95 |
| ARHEAT | 0,1 | Y | Heating equipment was added and removed since 1/95 |
| B4_78 | 0,1 | Y | Building was constructed before 1978 |
| CINDEX | ratio | X | (Cost-Rebate)/Cost |
| EMPCHG | 0,1 | Y | Employee change by 10% since 1/95 |
| GROCERY | 0,1 | Z | Grocery |
| HEALTH | 0,1 | Z | Health Care Building |
| HOTEL | 0,1 | Z | Hotel |
| HV_INFO | 0,1 | X | Made aware by HVAC contractor prior to purchase |
| MISCCOM | 0,1 | Z | Miscellaneous commercial building |
| OFFICE | 0,1 | Z | Office building |
| OWN | 0,1 | Y | Own building |
| PERSONL | 0,1 | Z | Personal services building |
| PGE_INFO | 0,1 | X | Made aware by PG&E representative prior to purchase |
| RESTR | 0,1 | Z | Restaurant |
| RETAIL | 0,1 | Z | Retail building |
| SCHOOL | 0,1 | Z | School |
| SFADD | 0,1 | Y | Square footage added to the facility |
| SHTLEASE | 0,1 | Y | Lease less than 1 year long |
| SQFEET | Square ft. | Y | Square footage of facility |
| TENACT | 0,1 | Y | Tenants active in equipment purchse decisions |
| WARE | 0,1 | Z | Warehouse |

There are four variables specified to capture the effect of the HVAC Program on the decision to make a purchase: AWARE, HV_INFO, PGE_INFO and CINDEX. For AWARE, customers are given a value of one if they indicated that they were aware of the retrofit program before they made the decision to purchase new CAC 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. This definition of awareness is used to take into account that the process of shopping for CAC 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 influenced them to shop for new CAC equipment. This precludes program awareness from having an effect on those customers who were already looking for CAC equipment when they became aware of the program.

Similar to the 1997 HVAC Program Evaluation, the variables HV_INFO and PGE_INFO are included to enhance the model's ability to identify the effects of program awareness. These two variables can take the value of either zero or one. HV_INFO takes on a value of one if:

1) the respondent was aware of the program prior to making the decision to purchase new CAC equipment, and

2) the respondent indicated they were informed of the program by their HVAC contractor

PGE_INFO is defined similarly, but indicates that the respondent received program information from their PG&E representative. Respondents who state they were aware of the program **and** are also able to state their source of information are likely to be more accurately and completely informed about the program. Perhaps more importantly, the addition of these two variables reduces the concern evaluators commonly have with customers falsely claming they are aware of the program. Allowing the impact of awareness to vary over these types of respondents improves the model's ability to interpret the impact of awareness. We expect that those who state they were aware of the program, and cite one or both of these two sources of information, will be more affected by their awareness.

Using this restricted definition of awareness, 64 percent of participant purchases were made by participants who were aware of the program. Approximately 14 percent of nonparticipants making CAC purchases were aware of the program before they made their purchase decision. For those that did not make any purchases, 16 percent were aware of the program. For the entire sample, 18 percent of the customers were coded as being aware of the HVAC Program.

Of those participants who were aware of the program, 38 percent claimed to have been made aware of the program by their HVAC contractor. Those who stated that their PG&E representative told them about the program comprised 44 percent of the participants who were aware. Among those who made out-of-program purchases and were aware, 26 percent received program information from their HVAC contractor; 48 percent from their PG&E representative. Overall, 33 percent of those who were aware received information from their PG&E representative, and 18 percent from their HVAC contractor.

The variable CINDEX gives the fraction of the incremental cost of the CAC 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 CAC equipment or were unaware of the program when the CAC 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 3-36. A likelihood ratio test yields a test statistic of over 1,565 with 23 degrees of freedom, which is well above the critical value at any of the conventional levels of significance. The coefficient estimates from the purchase model are shown in Exhibit 3-36, and the results generally conform to expectations. As expected, program awareness has a positive effect on the decision to purchase CAC equipment. Further, this effect is greater if either their HVAC contractor or PG&E representative informed the respondent of the program.

The coefficient estimate for CINDEX is negative. This suggests that the greater the percentage of costs that are paid by the customer, the less attractive it is 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 a CAC purchase. The facility size variable (SQFEET) is also positive, indicating that larger facilities are more likely to make CAC purchases. Not surprisingly, changes to the facility (ARLIGHT, ARHEAT, SFADD, EMPCHG) are also likely to lead to a CAC equipment purchase.

Recall the variable B4_78 is a dummy variable indicating whether a building was constructed before 1978. The coefficient for this variable is positive, confirming our expectation that older buildings would be more likely to be in need of new CAC equipment. The variable SHTLEASE is a dummy variable indicating whether a tenant has a lease less than one year long. Our expectation was that tenants with shorter leases would be less likely to purchase new CAC equipment. Our expectations were not borne out by the results, although the coefficient estimate is small and not statistically different from zero.

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

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

Where

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

*Exhibit 3-36*
*Purchase Model Estimation Results*

| Variable Name | Variable Type | Coefficient Estimate | Standard Error | Significance Level |
|---|---|---|---|---|
| AWARE | X | 0.22 | 0.22 | 33% |
| ARLIGHT | Y | 0.34 | 0.19 | 8% |
| ARHEAT | Y | 2.07 | 0.20 | 1% |
| B4_78 | Y | 0.34 | 0.16 | 3% |
| CINDEX | X | -4.03 | 0.34 | 1% |
| EMPCHG | Y | 0.13 | 0.21 | 53% |
| GROCERY | Z | 0.05 | 0.43 | 91% |
| HEALTH | Z | 0.32 | 0.32 | 32% |
| HOTEL | Z | 0.00 | 0.51 | 99% |
| HV_INFO | X | 1.06 | 0.32 | 1% |
| MISCCOM | Z | 0.33 | 0.32 | 30% |
| OFFICE | Z | 0.40 | 0.26 | 13% |
| OWN | Y | 1.34 | 0.26 | 1% |
| PERSONL | Z | 0.40 | 0.32 | 20% |
| PGE_INFO | X | 0.73 | 0.29 | 1% |
| RESTR | Z | -0.05 | 0.37 | 88% |
| RETAIL | Z | 0.01 | 0.31 | 97% |
| SCHOOL | Z | 0.19 | 0.37 | 60% |
| SFADD | Y | 1.07 | 0.26 | 1% |
| SHTLEASE | Y | 0.31 | 0.31 | 31% |
| SQFEET | Y | 2.81E-07 | 4.20E-07 | 50% |
| TENACT | Y | 0.82 | 0.28 | 1% |
| WARE | Z | -0.08 | 0.40 | 83% |

The estimated probabilities for different customer groups are given in Exhibit 3-37. HVAC Program participants have a higher probability of making an equipment purchase than those who made no purchase. However, the probability is still somewhat low at 27 percent. This is likely a result of the small number of rebated purchases included in the model. There were only a total of 58 such purchases included in the model. This restricted sample size reduces the reliability of the results. Those that did not make any purchases have a low estimated probability of purchasing high-efficiency equipment at 0.10.

The probability of making a CAC equipment purchase in absence of the program is calculated by removing the effect of the HVAC Program from the purchase decision model. This is done by setting AWARE, HV_INFO and PGE_INFO equal to zero and setting CINDEX equal to one to reflect the absence of a rebate. The probability of making a CAC 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 the absence of the HVAC Program are also given in Exhibit 3-37. In the absence of the HVAC Program, the probability of participants purchasing HVAC equipment drops from 0.27 to 0.12. This result suggests that the HVAC program has a measurable effect on participants' liklihood of making a purchase. As we would expect, the effect of the program on nonparticipants' purchase probability is more minor. Among those purchasing high-efficiency CAC equipment outside the program, removing the program effects decreases the purchase probability from 0.27 to 0.22.

*Exhibit 3-37*
*Estimated Purchase Probabilities*

| Customer Group | With Program | Without Program |
|---|---|---|
| No Purchase | 0.10 | 0.09 |
| Participants | 0.27 | 0.12 |
| Purchase HE Outside Program | 0.27 | 0.22 |
| Purchase Std Efficiency | 0.26 | 0.23 |

**Stage 2 -- Equipment Choice Model Specification**

The second stage of the model is devoted to estimating the probability that a specific CAC equipment option (i.e. high efficiency or standard efficiency) is chosen given that the decision to purchase CAC 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 CAC equipment. The choice set for the equipment choice model contains two different options: high-efficiency single and split AC units, and standard efficiency single and split AC units. As discussed earlier, in previous years evaporative coolers were included as a third equipment choice. However, the data this year would not support a separate category. There was only 1 participant in the sample that had made an evaporative cooler adoption through the program. High-efficiency split and single AC units, and standard efficiency single and split AC units were selected for the model as they comprised a large portion of the purchases made inside 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 nonchosen alternative.

The conditional logit model specification for equipment choice is:

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

Where

AWARE = Awareness of the retrofit program

HV_INFO = Respondent was made aware by HVAC contractor prior to purchase

PGE_INFO = Respondent was made aware by a PG&E representative prior to purchase

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

$\varepsilon$ = Random error term assumed logistically distributed.

The explanatory variables used in the equipment choice model are described in Exhibit 3-38. 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. This modified definition of aware is applied to the other awareness variables: HV_INFO and PGE_INFO. That is, HV_INFO was given a value of one if the respondent was aware of the program at the time new HVAC equipment was purchased **and** received program information from their HVAC contractor. PGE_INFO takes a value of one if the respondent was similarly aware, **and** was informed of the program by their PG&E representative.

*Exhibit 3-38*
*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 |
| GROCERY | 0,1 | Grocery |
| HEALTH | 0,1 | Health Care Building |
| HOTEL | 0,1 | Hotel |
| HV_INFO | 0,1 | Made aware of program by HVAC contractor |
| MISCCOM | 0,1 | Miscellaneous commercial building |
| OFFICE | 0,1 | Office building |
| PERSONL | 0,1 | Personal services building |
| PGE_INFO | 0,1 | Made aware of program by PG&E representative |
| PREDISP | 0,1 | Predisposition to buying high efficiency |
| RESTR | 0,1 | Restaurant |
| RETAIL | 0,1 | Retail building |
| SCHOOL | 0,1 | School |
| SAVINGS | dollars | Expected dollar amount of electricity savings |
| SQFEET | Square ft. | Square footage of facility |
| WARE | 0,1 | Warehouse |

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. 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. All of the variables except CINDEX and SAVINGS 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 customers 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 incremental cost that the customer must pay for equipment installation after any rebate has been paid. For those

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

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 alternative as well as for the equipment option actually chosen. How this information is calculated for nonchosen equipment alternative 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. 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. 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 3-39. The coefficient estimates for CINDEX and SAVINGS are contrary to a priori expectations. The coefficient estimate on CINDEX is positive and the coefficient estimate for SAVINGS is negative. These results suggest that greater rebate and savings values *reduce* the attractiveness of an equipment option. This counter-intuitive result is questionable and likely a result of an insufficient sample of participants.

*Exhibit 3-39*
*Equipment Choice Model Estimation Results*

| Variable Name | Coefficient Estimate | Standard Error | Significance Level |
|---|---|---|---|
| AWARE | 1.29 | 0.59 | 3% |
| CINDEX | 0.86 | 0.50 | 8% |
| GROCERY | 0.23 | 0.67 | 73% |
| HEALTH | 0.67 | 0.52 | 20% |
| HOTEL | -0.45 | 1.00 | 65% |
| HV_INFO | 2.62 | 0.89 | 1% |
| MISCOM | -1.27 | 0.52 | 1% |
| OFFICE | -0.68 | 0.36 | 6% |
| PREDISP | 2.04 | 0.49 | 1% |
| PGE_INFO | 0.22 | 0.55 | 69% |
| RETAIL | -0.63 | 0.45 | 16% |
| RESTR | 0.61 | 0.64 | 34% |
| SAVINGS | -5.99E-04 | 2.74E-04 | 3% |
| SCHOOL | 0.79 | 0.62 | 20% |
| SQFEET | 4.59E-06 | 2.90E-06 | 11% |
| WARE | -3.09 | 1.37 | 2% |

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. Further, both HV_INFO and PGE_INFO are positive, indicating the effect of awareness is greater for those who were made aware of the program through either their HVAC contrator or their PG&E representative.

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. SQFEET is the square footage of the facility interacted with a dummy variable for the high-efficiency equipment options. Here, the result is counter-intuitive. The coefficient estimate on SQFEET is negative (although small in magnitude), indicating a greater tendency for *smaller* buildings to purchase high efficiency equipment.

The remaining variables indicate business type. Of these, GROCERY, HEALTH, SCHOOL, and RESTR (restaurant) have positive coefficient estimates. Of all the business types, only WARE (warehouse) is statistically significant at the 95 percent confidence level.

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 both 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 both of the CAC equipment options. For participants, the probability of purchasing high-efficiency equipment is 0.86 with the program and falls to 0.51 without the program. This suggests that the HVAC Program is having a significant effect on high-efficiency CAC 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, HV_INFO, PGE_INFO 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 the awareness variables to zero and CINDEX equal to one to reflect the absence of rebates. While the awareness variables are set to zero, PREDISP retains its original value since this variable captures the effect of those that are predisposed to high-efficiency equipment and 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 making a CAC purchase since January of 1997, the weight was scaled down to reflect the portion of those adoptions which would have occurred during the pre-1998 program year carry-over. To estimate this portion a constant adoption rate over the 2 and ½ year period was assumed. That is, the 12 months of 1998 were divided by the 30 months spanning the period over which reported adoptions took place, which results in 40 percent. This percentage is used to adjust the nonparticipant weight. Finally, those that reported purchasing lighting outside the program since 1997 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 Pre-1998 HVAC Program Carry-Over.

To calculate expected impacts, the total probability of making a purchase with the program is multiplied by the gross impact associated with the technology. Please recall there is only one high efficiency equipment option, which is high efficiency split and packaged central air conditioners (CAC). The calculation is given by:

$$\text{EXPECTED IMPACT}^{w} = P^{w} * \text{IMPACT}$$

Where $P^{w}$ = Total probability of choosing

IMPACT = One year impact associated with high efficiency CAC equipment.

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

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

Where $P^{WO}$ = Total probability of choosing high efficiency CAC equipment option with the program.

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

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

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

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

The contributions to net made by participants (less free ridership), and through participant and nonparticipant spillover, can all be calculated separately using the two stage model.

For rebated participant actions, net impacts are calculated using the same method shown above:

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

For actions done outside the program, net impacts are calculated as:

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

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

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, the net-to-gross ratio is calculated for high efficiency CACs. The net-to-gross ratios for split and packaged CACs are shown in Exhibit 3-40. While the free ridership rate of 20.6 percent is within reasonable bounds, the participant and nonparticipant spillover rates are unusually high. There were 31 participants surveyed, who made 58 high efficiency CAC adoptions through the program in 1998. These same 31 participants made 22 high efficiency CAC adoptions outside the program, of which 20 contributed to participant spillover. Among nonparticipants, there were 79 high efficiency CAC adoptions. Of these, 14 contributed to nonparticipant spillover. However, the weight assigned to these nonparticipant adoptions is much greater than the participant adoptions due to the difference in the population sizes. With these statistics in mind, the results presented in Exhibit 3-40 below are reasonable and consistent with the data.

*Exhibit 3-40*
*Estimated NTG Ratios for Split and Packaged Central Air Conditioners*

| Split/Packaged CAC | |
|---|---|
| 1-FR | 79.42% |
| Participant Spillover | 19.88% |
| Nonparticipant Spillover | 58.94% |
| NTG | 158.24% |

### *3.4.4 Final Net-to-Gross Ratios*

As discussed above, three separate models were implemented to estimate the components of the net-to-gross ratio (free ridership and spillover). The first 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 second method used self-reported estimates of free ridership, participant spillover, and nonparticipant spillover. The final approach relied on a two-stage discrete choice model to estimate free ridership, participant spillover, and nonparticipant spillover for the CAC technology group only.

Given sufficient data to support the analysis, the most sophisticated and preferred of the three approaches is the two-stage discrete choice model. For the Pre-1998 HVAC Program Carry-Over, however, the small available participant sample renders the discrete choice result unreliable. The Mills ratios are run on a further reduced set of the data due to the censoring of customer billing data, and also lack the estimate of spillover. Given these circumstances, the self-report values provide the most comprehensive and accurate results of the three approaches.

Exhibit 3-41 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.

A comparison of the three models shows that the discrete choice results are not generally supported by the other approaches. The results can only be compared for the CAC technology group, where a discrete choice result was obtained. The rate of spillover for the CAC category is significantly higher compared the self-report technique, and free ridership is significantly lower. Overall, self report techniques yield a lower overall net to gross ratio for CACs. The impact on the total net to gross ratio of implementing the discrete choice results is minor. The total net to gross ratios calculated with self-report techniques are within one percent of those calculated using discrete choice results. This is true for the Retrofit Express Program, as well as all programs combined.

As mentioned above, the free ridership estimates using the Mills approach provide significantly higher estimates of net participation. This in part due to the large net estimates for custom measures.

*Exhibit 3-41*
*Comparison of Net-to-Gross Ratios*

| Program and Technology Group | | Discrete Choice Model NTG | Discrete Choice Model 1-FR | Discrete Choice Model Spill | Self Report NTG | Self Report 1-FR | Self Report Spill | Mills 1-FR |
|---|---|---|---|---|---|---|---|---|
| **Retrofit Express** | Central A/C | 1.58 | 0.79 | 0.79 | 0.59 | 0.45 | 0.14 | 0.95 |
| | Adjustable Speed Drives | - | - | - | 0.73 | 0.59 | 0.14 | 1.03 |
| | Package Terminal A/C | - | - | - | 1.04 | 0.90 | 0.14 | 1.03 |
| | Set-Back Thermostat | - | - | - | 0.70 | 0.56 | 0.14 | 1.03 |
| | Reflective Window Film | - | - | - | 0.36 | 0.22 | 0.14 | 1.03 |
| | Water Chillers | - | - | - | 0.90 | 0.76 | 0.14 | 0.91 |
| | Other HVAC Technologies | - | - | - | 0.14 | 0.00 | 0.14 | 1.03 |
| | ***Retrofit Express Program Total*** | 0.80 | 0.55 | 0.25 | 0.63 | 0.49 | 0.14 | 1.01 |
| **REO** | Adjustable Speed Drives | - | - | - | 0.73 | 0.59 | 0.14 | 1.03 |
| | Water Chillers | - | - | - | 0.90 | 0.76 | 0.14 | 0.91 |
| | Cooling Towers | - | - | - | 0.90 | 0.76 | 0.14 | 0.91 |
| | High Efficient Gas Boilers | - | - | - | 0.90 | 0.76 | 0.14 | 0.91 |
| | ***Retrofit Efficiency Options Program Total*** | 0.86 | 0.72 | 0.14 | 0.86 | 0.72 | 0.14 | 0.94 |
| **APO** | Water Chillers | - | - | - | 0.90 | 0.76 | 0.14 | 0.94 |
| | Customized EMS | - | - | - | 0.90 | 0.76 | 0.14 | 0.91 |
| | Customized Controls | - | - | - | 0.90 | 0.76 | 0.14 | 0.91 |
| | Convert To VAV | - | - | - | 0.90 | 0.76 | 0.14 | 0.91 |
| | Other Customized Equip | - | - | - | 0.90 | 0.76 | 0.14 | 0.91 |
| | Other HVAC Technologies | - | - | - | 0.90 | 0.76 | 0.14 | 0.91 |
| | ***Advanced Performance Options Program Total*** | 0.90 | 0.76 | 0.14 | 0.90 | 0.76 | 0.14 | 0.91 |
| | **Total** | **0.89** | **0.74** | **0.15** | **0.88** | **0.74** | **0.14** | **0.91** |

## Final NTG

The resulting net-to-gross ratios that were applied to the gross ex-post impacts are based on the self report model. The self report estimates are considered to be the most accurate. The discrete choice estimate for the CAC technology group was not supported by either the mills ratio or the self report results, and was conducted on a small sample participants. To be conservative and consistent, the self-report estimates of NTG were applied to all of the HVAC technology segments. Also, the CADMAC has approved a waiver that allows the use of self-report based algorithms to estimate free ridership and spillover effects in the event discrete choice and LIRM models fail to produce statistically reliable results. (The approved waiver is presented in Attachment 5.)

For all technology groups, 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 ratios are presented, weighted across business type by ex-post gross energy, demand and therm savings, respectively, in Exhibit 3-42.

*Exhibit 3-42*
*Final Net-to-Gross Ratios*

| Program and Technology Group | | Self Report Model NTG | 1-FR | Spill |
|---|---|---|---|---|
| **Retrofit Express** | Central A/C | 0.59 | 0.45 | 0.14 |
| | Adjustable Speed Drives | 0.73 | 0.59 | 0.14 |
| | Package Terminal A/C | 1.04 | 0.90 | 0.14 |
| | Set-Back Thermostat | 0.70 | 0.56 | 0.14 |
| | Reflective Window Film | 0.36 | 0.22 | 0.14 |
| | Water Chillers | 0.90 | 0.76 | 0.14 |
| | Other HVAC Technologies | 0.14 | - | 0.14 |
| ***Retrofit Express Program Total*** | | 0.63 | 0.49 | 0.14 |
| **REO** | Adjustable Speed Drives | 0.73 | 0.59 | 0.14 |
| | Water Chillers | 0.90 | 0.76 | 0.14 |
| | Cooling Towers | 0.90 | 0.76 | 0.14 |
| | High Efficient Gas Boilers | - | - | - |
| ***Retrofit Efficiency Options Program Total*** | | 0.86 | 0.72 | 0.14 |
| **APO** | Adjustable Speed Drives | 0.90 | 0.76 | 0.14 |
| | Water Chillers | 0.90 | 0.76 | 0.14 |
| | Customized EMS | 0.90 | 0.76 | 0.14 |
| | Convert To VAV | 0.90 | 0.76 | 0.14 |
| | Other Customized Equip | 0.90 | 0.76 | 0.14 |
| | Other HVAC Technologies | 0.90 | 0.76 | 0.14 |
| ***Advanced Performance Options Program Total*** | | 0.90 | 0.76 | 0.14 |
| **Totals Weighted by:** | | | | |
| | **Energy** | **0.88** | **0.74** | **0.14** |
| | **Demand** | **0.77** | **0.63** | **0.14** |
| | **Therm** | **0.88** | **0.74** | **0.14** |

## 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 surrounding the differences between the ex ante and ex post estimates are discussed in the presentation of program realization rates.

Where segment analysis could be supported, results are presented by technology group and business type. All results are segmented by program: Retrofit Express (RE), Retrofit Efficiency Options (REO), and Advanced Performance Options (APO). 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, and APO 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 | 79,745 | 13,428 | 7,841 | 7,612 | - | 31,793 | 34,422 | 1,858 | - | 17,348 | 46,775 | 7,526 | 248,348 |
| | Adjustable Speed Drives | 384,010 | - | - | - | - | - | - | - | - | 178,701 | 156,031 | - | 718,742 |
| | Package Terminal A/C | 2,765 | - | - | 861 | - | 8,040 | - | 28,257 | - | - | - | - | 39,923 |
| | Set-Back Thermostat | 31,457 | 16,304 | - | 50,861 | - | 6,661 | - | - | - | 7,804 | 40,673 | 6,290 | 160,051 |
| | Reflective Window Film | 131,560 | - | 3,969 | - | - | 2,675 | 87,054 | - | 17,387 | 15,606 | 3,647 | - | 261,899 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 17,278 | - | 17,278 |
| | Other HVAC Technologies | - | - | - | - | 47,754 | - | - | - | - | - | - | - | 47,754 |
| | Retrofit Express Program Total | 629,536 | 29,732 | 11,810 | 59,334 | 47,754 | 49,170 | 121,477 | 30,115 | 17,387 | 219,459 | 264,404 | 13,817 | 1,493,995 |
| REO | Adjustable Speed Drives | 306,617 | - | - | - | - | - | - | - | - | - | - | - | 306,617 |
| | Water Chillers | 45,363 | - | 61,872 | 89,065 | - | - | - | - | - | - | 60,560 | - | 256,860 |
| | Cooling Towers | - | - | 27,929 | 18,254 | - | - | 79,723 | - | - | - | 10,588 | - | 136,494 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Retrofit Efficiency Options Program Total | | 351,980 | 0 | 89,801 | 107,318 | 0 | 0 | 79,723 | 0 | 0 | 0 | 71,148 | 0 | 699,971 |
| APO | Water Chillers | 1,132,270 | - | - | - | - | - | 469,979 | - | - | 1,158,705 | 2,255,108 | - | 5,016,062 |
| | Customized EMS | 58,275 | - | 285,376 | - | - | - | - | - | - | 972,785 | - | - | 1,316,436 |
| | Customized Controls | 598,318 | - | - | - | - | - | 83,196 | - | - | - | - | - | 681,514 |
| | Convert To VAV | 402,303 | 27,081 | - | - | - | - | - | - | - | - | - | - | 429,384 |
| | Other Customized Equip | 1,044,029 | - | 1,099,595 | - | - | - | - | 815,300 | - | - | - | - | 2,958,924 |
| | Other HVAC Technologies | 231,740 | - | - | - | - | - | - | - | - | - | 831,945 | - | 1,063,685 |
| Advanced Performance Options Program Total | | 3,466,934 | 27,081 | 1,384,971 | 0 | 0 | 0 | 553,175 | 815,300 | 0 | 2,131,490 | 3,087,053 | 0 | 11,466,005 |
| Total | | 4,448,450 | 56,814 | 1,486,582 | 166,653 | 47,754 | 49,170 | 754,376 | 845,415 | 17,387 | 2,350,949 | 3,422,605 | 13,817 | 13,659,972 |

As shown in Exhibits 4-1 and 4-2, the APO program technologies represent approximately 84 percent of total energy and 76 percent of demand impacts. The RE and REO programs represent 11 percent and 5 percent of the energy impacts, respectively. These two programs represent about 12 percent of the total demand impacts each. By business segment, offices represent about one-third of overall energy impacts, and 40 percent of demand impacts.

Water Chillers which were offered through all three programs, contributed more to energy impacts than any other technology, with about 39 percent of the total. "Other Customized Equipment" installed under the APO program (including heat exchangers, VFDs, chiller and boiler replacements, controls, etc.) was the second largest contributor, having a total program impact representing about 22 percent of the total. Other technologies with relatively large shares of the impact were "Customized Energy Management Systems (EMS)" installed under the APO program, and "Other HVAC Technologies, "also installed under the APO program. These technology groups represent 9 and 8 percent of total program energy impacts, respectively.

***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 | 58 | 16 | 9 | 11 | - | 18 | 20 | 1 | - | 11 | 27 | 3 | 174 |
| | Adjustable Speed Drives | 69 | - | - | - | - | - | - | - | - | 36 | 15 | - | 119 |
| | Package Terminal A/C | 2 | - | - | 1 | - | 3 | - | 29 | - | - | - | - | 34 |
| | Set-Back Thermostat | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Reflective Window Film | 23 | - | 0.3 | - | - | 0.3 | 16 | - | 2 | 1 | 1 | - | 44 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 14 | - | 14 |
| | Other HVAC Technologies | - | - | - | - | 18 | - | - | - | - | - | - | - | 18 |
| | Retrofit Express Program Total | 151 | 16 | 9 | 12 | 18 | 21 | 36 | 30 | 2 | 48 | 56 | 3 | 403 |
| REO | Adjustable Speed Drives | 76 | - | - | - | - | - | - | - | - | - | - | - | 76 |
| | Water Chillers | 36 | - | 80 | 96 | - | - | - | - | - | - | 48 | - | 260 |
| | Cooling Towers | - | - | 43 | 22 | - | - | 32 | - | - | - | 11 | - | 106 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Retrofit Efficiency Options Program Total | | 112 | 0 | 123 | 117 | 0 | 0 | 32 | 0 | 0 | 0 | 59 | 0 | 442 |
| APO | Water Chillers | 864 | - | - | - | - | - | 200 | - | - | 99 | 542 | - | 1,705 |
| | Customized EMS | 99 | - | - | - | - | - | - | - | - | - | - | - | 99 |
| | Customized Controls | 73 | - | - | - | - | - | - | - | - | - | - | - | 73 |
| | Convert To VAV | 65 | 35 | - | - | - | - | - | - | - | - | - | - | 100 |
| | Other Customized Equip | 117 | - | 300 | - | - | - | - | 83 | - | - | - | - | 500 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 216 | - | 216 |
| Advanced Performance Options Program Total | | 1,217 | 35 | 300 | 0 | 0 | 0 | 200 | 83 | 0 | 99 | 758 | 0 | 2,692 |
| Total | | 1,481 | 51 | 431 | 129 | 18 | 21 | 268 | 113 | 2 | 147 | 873 | 3 | 3,538 |

Water Chillers contributed more to demand impacts than any other technology by far, with about 56 percent of the total. "Other Customized Equipment" installed under the APO program, had the second highest impact relative to other technology groups, with 14 percent.

Therm impacts associated with the installation of HVAC technologies paid in 1998 are presented next in Exhibit 4-3.

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.

*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 |
| REO | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Cooling Towers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | 2,507 | - | - | 2,507 |
| Retrofit Efficiency Options Program Total | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,507 | 0 | 0 | 2,507 |
| APO | Water Chillers | - | - | - | - | - | - | - | - | - | - | 89,512 | - | 89,512 |
| | Customized EMS | - | - | 26,768 | - | - | - | - | - | - | - | - | - | 26,768 |
| | Customized Controls | 48,028 | - | - | - | - | - | 8,545 | - | - | - | - | - | 56,573 |
| | Convert To VAV | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Other Customized Equip | 77,029 | - | 183,758 | - | - | - | - | - | - | - | - | - | 260,787 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 53,534 | - | 53,534 |
| Advanced Performance Options Program Total | | 125,057 | 0 | 210,526 | 0 | 0 | 0 | 8,545 | 0 | 0 | 0 | 143,046 | 0 | 487,174 |
| Total | | 125,057 | 0 | 210,526 | 0 | 0 | 0 | 8,545 | 0 | 0 | 2,507 | 143,046 | 0 | 489,681 |

Therm impacts were estimated for twelve APO applicants, mostly with EMS and system conversions from constant volume to variable air volume using VFDs. These measures were found in the office, community service, college/university, and health care/hospital business types.

## 4.2 NET-TO-GROSS ADJUSTMENTS

The NTG results are designed to account for all of the market 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 self report analysis were used. Refer to *Section 3.4, Net-to-Gross Analysis* for additional information surrounding the decision-making process. The overall NTG ratio was 0.87 based on both energy and demand savings, and 0.90 based on therm savings. Spillover was approximately 14 percent, overall. Finally, free-ridership was 27 percent based on energy and demand savings, and 24 percent based on therm savings. This variation is due to the distribution of ex-post energy, demand and therm savings across technologies.

*Exhibit 4-4*
*NTG Adjustments by Program and Technology Group*

| | | *Self Report Model* | | |
|---|---|---|---|---|
| ***Program and Technology Group*** | | ***NTG*** | ***1-FR*** | ***Spill*** |
| **Retrofit** | Central A/C | 0.59 | 0.45 | 0.14 |
| **Express** | Adjustable Speed Drives | 0.73 | 0.59 | 0.14 |
| | Package Terminal A/C | 1.04 | 0.90 | 0.14 |
| | Set-Back Thermostat | 0.70 | 0.56 | 0.14 |
| | Reflective Window Film | 0.36 | 0.22 | 0.14 |
| | Water Chillers | 0.90 | 0.76 | 0.14 |
| | Other HVAC Technologies | 0.14 | 0.00 | 0.14 |
| ***Retrofit Express Program Total*** | | 0.63 | 0.49 | 0.14 |
| **REO** | Adjustable Speed Drives | 0.73 | 0.59 | 0.14 |
| | Water Chillers | 0.90 | 0.76 | 0.14 |
| | Cooling Towers | 0.90 | 0.76 | 0.14 |
| | High Efficient Gas Boilers | 0.90 | 0.76 | 0.14 |
| ***Retrofit Efficiency Options Program Total*** | | 0.86 | 0.72 | 0.14 |
| **APO** | Water Chillers | 0.90 | 0.76 | 0.14 |
| | Customized EMS | 0.90 | 0.76 | 0.14 |
| | Customized Controls | 0.90 | 0.76 | 0.14 |
| | Convert To VAV | 0.90 | 0.76 | 0.14 |
| | Other Customized Equip | 0.90 | 0.76 | 0.14 |
| | Other HVAC Technologies | 0.90 | 0.76 | 0.14 |
| ***Advanced Performance Options Program Total*** | | 0.90 | 0.76 | 0.14 |
| **Totals Weighted by:** | | | | |
| **Energy** | | **0.87** | **0.73** | **0.14** |
| **Demand** | | **0.87** | **0.73** | **0.14** |
| **Therm** | | **0.90** | **0.76** | **0.14** |

## *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 and APO programs. These exhibits show reductions of 16 percent in ex post program energy impacts and 20 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.

The measures that contributed the majority of gross demand and energy savings provide the largest net impacts as well. These measures, which include Water Chillers and Other Customized Equipment, and Customized EMS measures installed through the APO program all had relatively high net-to-gross ratios, at 90 percent.

## *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 | 46,939 | 7,904 | 4,615 | 4,480 | - | 18,714 | 20,262 | 1,094 | - | 10,211 | 27,533 | 4,430 | 146,182 |
| | Adjustable Speed Drives | 281,563 | - | - | - | - | - | - | - | - | 131,027 | 114,404 | - | 526,994 |
| | Package Terminal A/C | 2,864 | - | - | 892 | - | 8,328 | - | 29,270 | - | - | - | - | 41,353 |
| | Set-Back Thermostat | 22,024 | 11,415 | - | 35,609 | - | 4,664 | - | - | - | 5,464 | 28,476 | 4,404 | 112,055 |
| | Reflective Window Film | 47,423 | - | 1,431 | - | - | 964 | 31,380 | - | 6,267 | 5,625 | 1,315 | - | 94,406 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 15,585 | - | 15,585 |
| | Other HVAC Technologies | - | - | - | - | 6,691 | - | - | - | - | - | - | - | 6,691 |
| | Retrofit Express Program Total | 400,812 | 19,319 | 6,046 | 40,981 | 6,691 | 32,670 | 51,642 | 30,363 | 6,267 | 152,328 | 187,313 | 8,834 | 943,267 |
| REO | Adjustable Speed Drives | 224,817 | - | - | - | - | - | - | - | - | - | - | - | 224,817 |
| | Water Chillers | 40,918 | - | 55,810 | 80,338 | - | - | - | - | - | - | 54,626 | - | 231,692 |
| | Cooling Towers | - | - | 25,193 | 16,465 | - | - | 71,912 | - | - | - | 9,550 | - | 123,120 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Retrofit Efficiency Options Program Total | | 265,735 | 0 | 81,002 | 96,803 | 0 | 0 | 71,912 | 0 | 0 | 0 | 64,177 | 0 | 579,629 |
| APO | Water Chillers | 1,021,327 | - | - | - | - | - | 423,929 | - | - | 1,045,173 | 2,034,148 | - | 4,524,577 |
| | Customized EMS | 52,565 | - | 257,414 | - | - | - | - | - | - | 877,469 | - | - | 1,187,448 |
| | Customized Controls | 539,693 | - | - | - | - | - | 75,045 | - | - | - | - | - | 614,738 |
| | Convert To VAV | 362,884 | 24,428 | - | - | - | - | - | - | - | - | - | - | 387,312 |
| | Other Customized Equip | 941,733 | - | 991,854 | - | - | - | - | 735,415 | - | - | - | - | 2,669,002 |
| | Other HVAC Technologies | 209,034 | - | - | - | - | - | - | - | - | - | 750,429 | - | 959,463 |
| Advanced Performance Options Program Total | | 3,127,236 | 24,428 | 1,249,268 | 0 | 0 | 0 | 498,974 | 735,415 | 0 | 1,922,642 | 2,784,577 | 0 | 10,342,540 |
| Total | | 3,793,784 | 43,747 | 1,336,317 | 137,784 | 6,691 | 32,670 | 622,528 | 765,778 | 6,267 | 2,074,969 | 3,036,066 | 8,834 | 11,865,436 |

## *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 | 34 | 10 | 5 | 7 | - | 10 | 12 | 1 | - | 6 | 16 | 2 | 102 |
| | Adjustable Speed Drives | 50 | - | - | - | - | - | - | - | - | 26 | 11 | - | 87 |
| | Package Terminal A/C | 2 | - | - | 1 | - | 3 | - | 30 | - | - | - | - | 35 |
| | Set-Back Thermostat | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Reflective Window Film | 8 | - | 0 | - | - | 0 | 6 | - | 1 | 1 | 0 | - | 16 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 13 | - | 13 |
| | Other HVAC Technologies | - | - | - | - | 3 | - | - | - | - | - | - | - | 3 |
| | Retrofit Express Program Total | 95 | 10 | 5 | 7 | 3 | 13 | 18 | 30 | 1 | 33 | 40 | 2 | 256 |
| REO | Adjustable Speed Drives | 56 | - | - | - | - | - | - | - | - | - | - | - | 56 |
| | Water Chillers | 33 | - | 72 | 86 | - | - | - | - | - | - | 43 | - | 234 |
| | Cooling Towers | - | - | 38 | 19 | - | - | 28 | - | - | - | 10 | - | 96 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Retrofit Efficiency Options Program Total | | 88 | 0 | 110 | 106 | 0 | 0 | 28 | 0 | 0 | 0 | 53 | 0 | 386 |
| APO | Water Chillers | 779 | - | - | - | - | - | 180 | - | - | 89 | 489 | - | 1,538 |
| | Customized EMS | 89 | - | - | - | - | - | - | - | - | - | - | - | 89 |
| | Customized Controls | 66 | - | - | - | - | - | - | - | - | - | - | - | 66 |
| | Convert To VAV | 59 | 31 | - | - | - | - | - | - | - | - | - | - | 90 |
| | Other Customized Equip | 106 | - | 271 | - | - | - | - | 75 | - | - | - | - | 451 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 195 | - | 195 |
| Advanced Performance Options Program Total | | 1,098 | 31 | 271 | 0 | 0 | 0 | 180 | 75 | 0 | 89 | 684 | 0 | 2,429 |
| Total | | 1,281 | 41 | 386 | 113 | 3 | 13 | 227 | 105 | 1 | 122 | 776 | 2 | 3,071 |

The net demand picture remained the same as gross. Net therm impacts, summarized in Exhibit 4-7, differ from the gross therm impacts by only 10 percent, overall.

## *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 |
| REO | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Cooling Towers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | 2,261 | - | - | 2,261 |
| Retrofit Efficiency Options Program Total | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,261 | 0 | 0 | 2,261 |
| APO | Water Chillers | - | - | - | - | - | - | - | - | - | - | 80,741 | - | 80,741 |
| | Customized EMS | - | - | 24,145 | - | - | - | - | - | - | - | - | - | 24,145 |
| | Customized Controls | 43,322 | - | - | - | - | - | 7,707 | - | - | - | - | - | 51,030 |
| | Convert To VAV | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Other Customized Equip | 69,482 | - | 165,753 | - | - | - | - | - | - | - | - | - | 235,234 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 48,289 | - | 48,289 |
| Advanced Performance Options Program Total | | 112,804 | 0 | 189,898 | 0 | 0 | 0 | 7,707 | 0 | 0 | 0 | 129,030 | 0 | 439,440 |
| **Total** | | 112,804 | 0 | 189,898 | 0 | 0 | 0 | 7,707 | 0 | 0 | 2,261 | 129,030 | 0 | **441,701** |

### *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 and APO programs. 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 | 1.04 | 0.56 | 0.16 | 0.36 | - | 0.91 | 0.69 | 1.83 | - | 1.03 | 0.84 | 1.12 | 0.74 |
| | Adjustable Speed Drives | 2.12 | - | - | - | - | - | - | - | - | 2.37 | 2.96 | - | 2.33 |
| | Package Terminal A/C | 1.18 | - | - | 1.43 | - | 0.96 | - | 0.98 | - | - | - | - | 0.99 |
| | Set-Back Thermostat | 0.55 | 1.00 | - | 0.59 | - | 0.54 | - | - | - | 0.64 | 0.83 | 1.54 | 0.67 |
| | Reflective Window Film | 1.19 | - | 1.19 | - | - | 1.19 | 1.19 | - | 1.19 | 1.19 | 1.19 | - | 1.19 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 0.76 | - | 0.76 |
| | Other HVAC Technologies | - | - | - | - | 1.19 | - | - | - | - | - | - | - | 1.19 |
| Retrofit Express Program Total | | 1.47 | 0.74 | 0.23 | 0.55 | 1.19 | 0.85 | 0.99 | 1.00 | 1.19 | 1.87 | 1.44 | 1.27 | 1.24 |
| REO | Adjustable Speed Drives | 0.82 | - | - | - | - | - | - | - | - | - | - | - | 0.82 |
| | Water Chillers | 0.91 | - | 0.16 | 0.56 | - | - | - | - | - | - | 0.29 | - | 0.32 |
| | Cooling Towers | - | - | 0.17 | 0.23 | - | - | 0.76 | - | - | - | 0.15 | - | 0.32 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Retrofit Efficiency Options Program Total | | 0.83 | - | 0.16 | 0.45 | - | - | 0.76 | - | - | - | 0.25 | - | 0.44 |
| APO | Water Chillers | 0.42 | - | - | - | - | - | 0.27 | - | - | 0.76 | 0.76 | - | 0.56 |
| | Customized EMS | 0.10 | - | 0.76 | - | - | - | - | - | - | 0.76 | - | - | 0.51 |
| | Customized Controls | 1.17 | - | - | - | - | - | 0.70 | - | - | - | - | - | 1.08 |
| | Convert To VAV | 0.76 | 0.80 | - | - | - | - | - | - | - | - | - | - | 0.76 |
| | Other Customized Equip | 0.76 | - | 0.76 | - | - | - | - | 0.79 | - | - | - | - | 0.77 |
| | Other HVAC Technologies | 1.00 | - | - | - | - | - | - | - | - | - | 0.76 | - | 0.80 |
| Advanced Performance Options Program Total | | 0.59 | 0.80 | 0.76 | - | - | - | 0.25 | 0.79 | - | 0.76 | 0.76 | - | 0.64 |
| **Total** | | 0.66 | 0.77 | 0.61 | 0.48 | 1.19 | 0.85 | 0.31 | 0.80 | 1.19 | 0.80 | 0.75 | 1.27 | **0.66** |

Exhibit 4-8 illustrates that the ex post impacts are somewhat lower than the ex ante estimates overall. The realization rates for the REO and APO programs are well below 1, while the RE program realization rate is well above 1. This is due primarily to two factors. First, on-site audits and engineering analyses of customized HVAC installations within the REO and APO programs also uncovered lower energy impacts than predicted by ex ante estimates. Second, the SAE analysis detected less savings than was predicted by the engineering analyses for the REO and APO programs. At the same time, the SAE analysis detected more savings than predicted within the RE program.

Among the technology groups, Water Chillers and "Customized Energy Management Systems (EMS)" have the greatest impact on the overall realization rate, because they represent the greatest portion of total energy impacts. These technology groups both had an SAE coefficient of 0.76, and received further downward adjustments (within the APO and REO programs) due to the results of engineering analyses, as discussed below. A relatively high realization rate was found within the Adjustable Speed Drive technology group.

Overall, realization rate by business type and technology group vary dramatically, ranging from 0.16 to 2.33. 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.

**Water Chillers:** The water chiller realization rates differed significantly by program, ranging from 76 percent for RE to 32 percent for REO. These differences are due to the variety of ex ante methodologies being applied across program and chiller type. For example, the RE program savings are based on the tonnage of the unit installed, whereas the REO program savings are based on the square footage of the facility. The ex post estimates are based upon calibrated engineering results and the SAE results. The engineering analysis 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. The SAE adjustment was 0.76, contributing to the relatively low overall gross realization rate results for water chillers.

**Other REO and APO Measures:** In general, the differences 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 APO 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.

**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. In addition, the resulting SAE coefficient of 1.15, also contributed to this difference

In contrast, the ex post adjustable speed drive results are fairly similar to 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 RE, REO and APO 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.*

### *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.

Overall, the gross demand estimates are 12 percent higher than the ex ante values, as illustrated in Exhibit 4-9 above. Some of the results can be explained using information from review of the ex ante estimates and the evaluation engineering analysis. The rates for Customized Controls and Adjustable Speed Drives are particularly high. The rate for Reflective Window film is also notably high. The rate for CAC is somewhat low, at 76 percent. The remaining rates are near one. Specific comments and justifications for rates differing notably from one follow:

*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 | 0.87 | 0.64 | 0.29 | 1.11 | - | 0.77 | 0.86 | 0.87 | - | 0.98 | 0.74 | 1.01 | 0.76 |
| | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Package Terminal A/C | 1.03 | - | - | 1.81 | - | 0.50 | - | 0.90 | - | - | - | - | 0.86 |
| | Set-Back Thermostat | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Reflective Window Film | 1.27 | - | 0.58 | - | - | 0.72 | 1.37 | - | 1.01 | 0.71 | 1.13 | - | 1.23 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 1.00 | - | 1.00 |
| | Other HVAC Technologies | - | - | - | - | 1.03 | - | - | - | - | - | - | - | 1.03 |
| | Retrofit Express Program Total | 1.75 | 0.64 | 0.30 | 1.13 | 1.03 | 0.71 | 1.03 | 0.90 | 1.01 | 3.69 | 1.10 | 1.01 | 1.20 |
| REO | Adjustable Speed Drives | 14.38 | - | - | - | - | - | - | - | - | - | - | - | 14.38 |
| | Water Chillers | 1.33 | - | 0.78 | 1.45 | - | - | - | - | - | - | 0.71 | - | 0.99 |
| | Cooling Towers | - | - | 1.39 | 1.27 | - | - | 1.00 | - | - | - | 1.08 | - | 1.19 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Retrofit Efficiency Options Program Total | | 3.46 | - | 0.92 | 1.41 | - | - | 1.00 | - | - | - | 0.76 | - | 1.24 |
| APO | Water Chillers | 1.23 | - | - | - | - | - | 1.04 | - | - | 1.00 | 1.00 | - | 1.11 |
| | Customized EMS | 1.59 | - | - | - | - | - | - | - | - | - | - | - | 0.77 |
| | Customized Controls | 24.40 | - | - | - | - | - | - | - | - | - | - | - | 24.40 |
| | Convert To VAV | 1.00 | 1.58 | - | - | - | - | - | - | - | - | - | - | 1.15 |
| | Other Customized Equip | 1.00 | - | 1.00 | - | - | - | - | 1.10 | - | - | - | - | 1.02 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 1.00 | - | 1.00 |
| Advanced Performance Options Program Total | | 1.28 | 1.58 | 1.00 | - | - | - | 0.78 | 1.10 | - | 1.00 | 1.00 | - | 1.09 |
| Total | | 1.38 | 1.08 | 0.93 | 1.38 | 1.03 | 0.71 | 0.83 | 1.04 | 1.01 | 1.31 | 0.98 | 1.01 | 1.12 |

**Customized Controls –** This result is based on two sites. The first had very minimal impacts, 3 kW, which was corroborated by the ex post engineering analysis. The second site, however, had an ex ante demand impact estimate of zero, while the ex post engineering analysis revealed an impact of 74.68 kW. In particular, it was found that the installed controls turned off lights that were normally left on during the peak demand period.

**Adjustable Speed Drives (ASDs):** Relatively large impacts were observed for ASD measures installed under the RE program. 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.

**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.*

**Central Air Conditioners:** Unadjusted ex post energy impacts are only 64 percent of ex ante impacts. This is due to changes that occurred in the ex ante design algorithms from 1996 to 1997. The coincident demand savings for the most commonly installed CAC increased from 0.075 to 0.159 kW per ton per change in SEER; an increase of over 100 percent. The effect of this discrepancy was dampened by the results of the SAE analysis, which detected 15 percent more savings than predicted by engineering estimates.

### *4.4.3 Gross Realization Rates for Therm Impacts*

Gross realization rates for therm impacts are provided in Exhibit 4-10. Therm impacts were estimated for twelve APO applicants, mostly with EMS and system conversions from constant volume to variable air volume using VFDs. These measures were found in the office, community service, college/university, and health care/hospital business types. Each site underwent a thorough engineering review of the application, which resulted in accepting the ex ante estimate in all but two of the sites.

***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 | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| REO | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Cooling Towers | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | 1.00 | - | - | 1.00 |
| Retrofit Efficiency Options Program Total | | - | - | - | - | - | - | - | - | - | 1.00 | - | - | 1.00 |
| APO | Water Chillers | - | - | - | - | - | - | - | - | - | - | 1.00 | - | 1.00 |
| | Customized EMS | - | - | 1.00 | - | - | - | - | - | - | - | - | - | 0.25 |
| | Customized Controls | 0.91 | - | - | - | - | - | 0.87 | - | - | - | - | - | 0.90 |
| | Convert To VAV | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Other Customized Equip | 1.00 | - | 1.00 | - | - | - | - | - | - | - | - | - | 1.00 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 1.00 | - | 1.00 |
| Advanced Performance Options Program Total | | 0.96 | - | 1.00 | - | - | - | 0.10 | - | - | - | 1.00 | - | 0.85 |
| **Total** | | 0.96 | - | 1.00 | - | - | - | 0.10 | - | - | 1.00 | 1.00 | - | **0.85** |

### *4.4.4 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 made 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 higher ex post NTG ratio applied to several key analysis segments. Specifically, the ex post net-to-gross adjustment applied to all APO technologies was 0.90, versus the ex ante adjustment of 0.75. Similarly, the cooling towers and water chillers within the REO program received higher ex post NTG adjustments versus ex ante, 0.88 for water chillers and 0.90 for cooling towers. These segments account for 92 percent of the ex post net energy impacts.

***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 | 0.80 | 0.43 | 0.12 | 0.27 | - | 0.70 | 0.53 | 1.40 | - | 0.79 | 0.64 | 0.85 | 0.56 |
| | Adjustable Speed Drives | 2.02 | - | - | - | - | - | - | - | - | 2.26 | 2.82 | - | 2.22 |
| | Package Terminal A/C | 1.59 | - | - | 1.92 | - | 1.29 | - | 1.31 | - | - | - | - | 1.33 |
| | Set-Back Thermostat | 0.50 | 0.91 | - | 0.54 | - | 0.49 | - | - | - | 0.58 | 0.75 | 1.40 | 0.61 |
| | Reflective Window Film | 0.56 | - | 0.56 | - | - | 0.56 | 0.56 | - | 0.56 | 0.56 | 0.56 | - | 0.56 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 0.89 | - | 0.89 |
| | Other HVAC Technologies | - | - | - | - | 0.22 | - | - | - | - | - | - | - | 0.22 |
| | Retrofit Express Program Total | 1.22 | 0.62 | 0.15 | 0.49 | 0.22 | 0.73 | 0.54 | 1.32 | 0.56 | 1.68 | 1.32 | 1.06 | 1.02 |
| REO | Adjustable Speed Drives | 0.80 | - | - | - | - | - | - | - | - | - | - | - | 0.80 |
| | Water Chillers | 1.09 | - | 0.19 | 0.67 | - | - | - | - | - | - | 0.35 | - | 0.38 |
| | Cooling Towers | - | - | 0.20 | 0.27 | - | - | 0.91 | - | - | - | 0.18 | - | 0.39 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Retrofit Efficiency Options Program Total | | 0.84 | - | 0.20 | 0.54 | - | - | 0.91 | - | - | - | 0.30 | - | 0.48 |
| APO | Water Chillers | 0.51 | - | - | - | - | - | 0.33 | - | - | 0.91 | 0.91 | - | 0.68 |
| | Customized EMS | 0.13 | - | 0.91 | - | - | - | - | - | - | 0.91 | - | - | 0.62 |
| | Customized Controls | 1.40 | - | - | - | - | - | 0.85 | - | - | - | - | - | 1.30 |
| | Convert To VAV | 0.91 | 0.96 | - | - | - | - | - | - | - | - | - | - | 0.91 |
| | Other Customized Equip | 0.91 | - | 0.92 | - | - | - | - | 0.96 | - | - | - | - | 0.93 |
| | Other HVAC Technologies | 1.21 | - | - | - | - | - | - | - | - | - | 0.91 | - | 0.96 |
| Advanced Performance Options Program Total | | 0.71 | 0.96 | 0.92 | - | - | - | 0.30 | 0.96 | - | 0.91 | 0.91 | - | 0.77 |
| **Total** | | 0.75 | 0.77 | 0.73 | 0.52 | 0.22 | 0.73 | 0.34 | 0.97 | 0.56 | 0.94 | 0.89 | 1.06 | 0.76 |

## *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 | 0.66 | 0.49 | 0.22 | 0.85 | - | 0.59 | 0.66 | 0.66 | - | 0.75 | 0.57 | 0.77 | 0.58 |
| | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Package Terminal A/C | 1.39 | - | - | 2.44 | - | 0.67 | - | 1.22 | - | - | - | - | 1.16 |
| | Set-Back Thermostat | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Reflective Window Film | 0.59 | - | 0.27 | - | - | 0.34 | 0.64 | - | 0.47 | 0.33 | 0.53 | - | 0.58 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 1.17 | - | 1.17 |
| | Other HVAC Technologies | - | - | - | - | 0.19 | - | - | - | - | - | - | - | 0.19 |
| Retrofit Express Program Total | | 1.42 | 0.49 | 0.22 | 0.89 | 0.19 | 0.60 | 0.65 | 1.20 | 0.47 | 3.31 | 1.01 | 0.77 | 0.99 |
| REO | Adjustable Speed Drives | 14.05 | - | - | - | - | - | - | - | - | - | - | - | 14.05 |
| | Water Chillers | 1.60 | - | 0.94 | 1.74 | - | - | - | - | - | - | 0.86 | - | 1.19 |
| | Cooling Towers | - | - | 1.67 | 1.53 | - | - | 1.20 | - | - | - | 1.30 | - | 1.43 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Retrofit Efficiency Options Program Total | | 3.63 | - | 1.11 | 1.70 | - | - | 1.20 | - | - | - | 0.91 | - | 1.44 |
| APO | Water Chillers | 1.47 | - | - | - | - | - | 1.25 | - | - | 1.20 | 1.20 | - | 1.33 |
| | Customized EMS | 1.91 | - | - | - | - | - | - | - | - | - | - | - | 0.93 |
| | Customized Controls | 29.35 | - | - | - | - | - | - | - | - | - | - | - | 29.35 |
| | Convert To VAV | 1.20 | 1.90 | - | - | - | - | - | - | - | - | - | - | 1.38 |
| | Other Customized Equip | 1.20 | - | 1.20 | - | - | - | - | 1.33 | - | - | - | - | 1.22 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 1.20 | - | 1.20 |
| Advanced Performance Options Program Total | | 1.54 | 1.90 | 1.20 | - | - | - | 0.93 | 1.33 | - | 1.20 | 1.20 | - | 1.31 |
| **Total** | | 1.59 | 1.13 | 1.11 | 1.60 | 0.19 | 0.60 | 0.93 | 1.29 | 0.47 | 1.45 | 1.17 | 0.77 | **1.29** |

## *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 | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| REO | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Cooling Towers | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | 1.20 | - | - | 1.20 |
| Retrofit Efficiency Options Program Total | | - | - | - | - | - | - | - | - | - | 1.20 | - | - | 1.20 |
| APO | Water Chillers | - | - | - | - | - | - | - | - | - | - | 1.20 | - | 1.20 |
| | Customized EMS | - | - | 1.20 | - | - | - | - | - | - | - | - | - | 0.30 |
| | Customized Controls | 1.09 | - | - | - | - | - | 1.05 | - | - | - | - | - | 1.08 |
| | Convert To VAV | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Other Customized Equip | 1.20 | - | 1.20 | - | - | - | - | - | - | - | - | - | 1.20 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 1.20 | - | 1.20 |
| Advanced Performance Options Program Total | | 1.16 | - | 1.20 | - | - | - | 0.11 | - | - | - | 1.20 | - | 1.02 |
| **Total** | | 1.16 | - | 1.20 | - | - | - | 0.11 | - | - | 1.20 | 1.20 | - | **1.02** |

## 4.5 OVERVIEW OF REALIZATION RATES

The ex post gross impacts are somewhat lower than the predicted ex ante impact estimates for energy. This is due to the results of SAE analysis, which detected 24 percent less impacts for all technologies within the APO program, and most technologies within the REO program. In addition, the ex post engineering analyses found less energy impacts than predicted by ex ante estimates for some key technology segments including Water Chillers, which accounted for 39 percent of gross energy impacts. The ex post demand impacts, however, exceed ex ante impacts by 12 percent. This is due primarily to higher ex post demand impacts found in Adjustable Speed Drives, Customized Controls, and Reflective Window Film, as discussed above.

Higher ex post net to gross adjustments relative to ex ante resulted in higher net realization rates relative to gross realization rates. The ex ante NTG adjustment was 0.75, while the ex post adjustment was somewhat higher on average, 0.87. For energy impacts, where ex post gross impacts were 24 percent lower than ex ante, the net realization rate was closer to one, at 76 percent. Conversely, for demand impacts, where ex post gross impacts were 12 percent higher than ex ante estimates, the net realization rate was further from one, at 1.29. Exhibit 4-14 below presents a summary of gross and net program impacts, as well as NTG adjustments and realization rates.

## *Exhibit 4-14*
## *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 |
| | | | **EX ANTE** | | | | | | |
| Retrofit | Central A/C | 336,445 | 230 | 0 | 0.67 | 0.10 | 259,015 | 177 | 0 |
| Express | Adjustable Speed Drives | 308,787 | 0 | 0 | 0.67 | 0.10 | 237,722 | 0 | 0 |
| | Package Terminal A/C | 40,312 | 40 | 0 | 0.67 | 0.10 | 31,035 | 31 | 0 |
| | Set-Back Thermostat | 237,437 | 0 | 0 | 0.67 | 0.10 | 182,793 | 0 | 0 |
| | Reflective Window Film | 220,514 | 36 | 0 | 0.67 | 0.10 | 169,765 | 27 | 0 |
| | Water Chillers | 22,804 | 14 | 0 | 0.67 | 0.10 | 17,556 | 11 | 0 |
| | Other HVAC Technologies | 40,255 | 17 | 0 | 0.67 | 0.10 | 30,991 | 13 | 0 |
| **Retrofit Express Program Total** | | 1,206,555 | 337 | 0 | 0.67 | 0.10 | 928,877 | 260 | 0 |
| REO | Adjustable Speed Drives | 372,699 | 5 | 0 | 0.65 | 0.10 | 279,473 | 4 | 0 |
| | Water Chillers | 805,343 | 263 | 0 | 0.65 | 0.10 | 603,897 | 197 | 0 |
| | Cooling Towers | 426,262 | 89 | 0 | 0.65 | 0.10 | 319,638 | 67 | 0 |
| | High Efficiency Gas Boilers | 0 | 0 | 2,507 | 0.65 | 0.10 | 0 | 0 | 1,880 |
| **Retrofit Efficiency Options Program Total** | | 1,604,304 | 357 | 2,507 | 0.65 | 0.10 | 1,203,008 | 268 | 1,880 |
| APO | Water Chillers | 8,914,534 | 1,538 | 89,512 | 0.65 | 0.10 | 6,684,676 | 1,154 | 67,134 |
| | Customized EMS | 2,574,785 | 128 | 106,589 | 0.65 | 0.10 | 1,930,735 | 96 | 79,942 |
| | Customized Controls | 631,109 | 3 | 62,858 | 0.65 | 0.10 | 473,245 | 2 | 47,144 |
| | Convert To VAV | 564,749 | 87 | 0 | 0.65 | 0.10 | 423,485 | 65 | 0 |
| | Other Customized Equip | 3,846,982 | 492 | 260,787 | 0.65 | 0.10 | 2,884,708 | 369 | 195,590 |
| | Other HVAC Technologies | 1,328,775 | 216 | 53,534 | 0.65 | 0.10 | 996,399 | 162 | 40,151 |
| **Advanced Performance Options Program Total** | | 17,860,934 | 2,464 | 573,280 | 0.65 | 0.10 | 13,393,247 | 1,848 | 429,960 |
| **Total** | | 20,671,794 | 3,159 | 575,787 | 0.65 | 0.10 | 15,525,132 | 2,376 | 431,840 |
| | | | **EX POST** | | | | | | |
| Retrofit | Central A/C | 248,348 | 174 | 0 | 0.45 | 0.14 | 146,182 | 102 | 0 |
| Express | Adjustable Speed Drives | 718,742 | 119 | 0 | 0.59 | 0.14 | 526,994 | 87 | 0 |
| | Package Terminal A/C | 39,923 | 34 | 0 | 0.90 | 0.14 | 41,353 | 35 | 0 |
| | Set-Back Thermostat | 160,051 | 0 | 0 | 0.56 | 0.14 | 112,055 | 0 | 0 |
| | Reflective Window Film | 261,899 | 44 | 0 | 0.22 | 0.14 | 94,406 | 16 | 0 |
| | Water Chillers | 17,278 | 14 | 0 | 0.76 | 0.14 | 15,585 | 13 | 0 |
| | Other HVAC Technologies | 47,754 | 18 | 0 | 0.00 | 0.14 | 6,691 | 3 | 0 |
| **Retrofit Express Program Total** | | 1,493,995 | 403 | 0 | 0.49 | 0.14 | 943,267 | 256 | 0 |
| REO | Adjustable Speed Drives | 306,617 | 76 | 0 | 0.59 | 0.14 | 224,817 | 56 | 0 |
| | Water Chillers | 256,860 | 260 | 0 | 0.76 | 0.14 | 231,692 | 234 | 0 |
| | Cooling Towers | 136,494 | 106 | 0 | 0.76 | 0.14 | 123,120 | 96 | 0 |
| | High Efficiency Gas Boilers | 0 | 0 | 2,507 | 0.76 | 0.14 | 0 | 0 | 2,261 |
| **Retrofit Efficiency Options Program Total** | | 699,971 | 442 | 2,507 | 0.69 | 0.14 | 579,629 | 386 | 2,261 |
| APO | Water Chillers | 5,016,062 | 1,705 | 89,512 | 0.76 | 0.14 | 4,524,577 | 1,538 | 80,741 |
| | Customized EMS | 1,316,436 | 99 | 26,768 | 0.76 | 0.14 | 1,187,448 | 89 | 24,145 |
| | Customized Controls | 681,514 | 73 | 56,573 | 0.76 | 0.14 | 614,738 | 66 | 51,030 |
| | Convert To VAV | 429,384 | 100 | 0 | 0.76 | 0.14 | 387,312 | 90 | 0 |
| | Other Customized Equip | 2,958,924 | 500 | 260,787 | 0.76 | 0.14 | 2,669,002 | 451 | 235,234 |
| | Other HVAC Technologies | 1,063,685 | 216 | 53,534 | 0.76 | 0.14 | 959,463 | 195 | 48,289 |
| **Advanced Performance Options Program Total** | | 11,466,005 | 2,692 | 487,174 | 0.76 | 0.14 | 10,342,540 | 2,429 | 439,440 |
| **Total** | | 13,659,972 | 3,538 | 489,681 | 0.73 | 0.14 | 11,865,436 | 3,071 | 441,701 |

*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 | 0.74 | 0.76 | - | - | - | 0.56 | 0.58 | - |
| Express | Adjustable Speed Drives | 2.33 | - | - | - | - | 2.22 | - | - |
| | Package Terminal A/C | 0.99 | 0.86 | - | - | - | 1.33 | 1.16 | - |
| | Set-Back Thermostat | 0.67 | - | - | - | - | 0.61 | - | - |
| | Reflective Window Film | 1.19 | 1.23 | - | - | - | 0.56 | 0.58 | - |
| | Water Chillers | 0.76 | 1.00 | - | - | - | 0.89 | 1.17 | - |
| | Other HVAC Technologies | 1.19 | 1.03 | - | - | - | 0.22 | 0.19 | - |
| **Retrofit Express Program Total** | | 1.24 | 1.20 | - | - | - | 1.02 | 0.99 | - |
| REO | Adjustable Speed Drives | 0.82 | 14.38 | - | - | - | 0.80 | 14.05 | - |
| | Water Chillers | 0.32 | 0.99 | - | - | - | 0.38 | 1.19 | - |
| | Cooling Towers | 0.32 | 1.19 | - | - | - | 0.39 | 1.43 | - |
| | High Efficiency Gas Boilers | - | - | 1.00 | - | - | - | - | 1.20 |
| **Retrofit Efficiency Options Program Total** | | 0.44 | 1.24 | 1.00 | - | - | 0.48 | 1.44 | 1.20 |
| APO | Water Chillers | 0.56 | 1.11 | 1.00 | - | - | 0.68 | 1.33 | 1.20 |
| | Customized EMS | 0.51 | 0.77 | 0.25 | - | - | 0.62 | 0.93 | 0.30 |
| | Customized Controls | 1.08 | 24.40 | 0.90 | - | - | 1.30 | 29.35 | 1.08 |
| | Convert To VAV | 0.76 | 1.15 | - | - | - | 0.91 | 1.38 | - |
| | Other Customized Equip | 0.77 | 1.02 | 1.00 | - | - | 0.93 | 1.22 | 1.20 |
| | Other HVAC Technologies | 0.80 | 1.00 | 1.00 | - | - | 0.96 | 1.20 | 1.20 |
| **Advanced Performance Options Program Total** | | 0.64 | 1.09 | 0.85 | - | - | 0.77 | 1.31 | 1.02 |
| **Total** | | 0.66 | 1.12 | 0.85 | - | - | 0.76 | 1.29 | 1.02 |

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

*Attachments*

*Attachment 1*

*Custom HVAC Analysis*

**Customized Space Conditioning (Site 164)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | Space Conditioning (Customized) |
| Site Description | Office |

**Measure Description** Replace chiller, boiler, fan coil units, and controls; convert from 3-pipe to 4-pipe water return system; install variable frequency drives (VFD's) on all new air handlers.

**Summary of Ex Ante Impact Calculations** Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and all HVAC plant and system characteristics.

**Comments on PG&E Calculations** The correct climate zone and building characteristics were used in the application.

**Evaluation Process** The evaluation process consisted of reviewing the application form and supporting documentation. An on-site survey was attempted on September 29, 1999 in San Jose (Climate Zone 4). The contact was unable to provide access to any of the retrofit equipment. Future attempts at rescheduling the on-site were unsuccessful. Due to the difficulties associated with this site, a thorough review of the application was conducted. Ex ante impact estimates are accepted as accurate.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 117 | 1,377,912.44 | 77,029 |
| **Adjusted Engineering** | 117 | 1,377,912.44 | 77,029 |
| **Engineering Realization Rate** | 1.00 | 1.00 | 1.00 |

**Customized Space Conditioning (Site 166)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | Space Conditioning (Customized) |
| Site Description | Community Service |

**Measure Description** Replace chiller and cooling tower; convert mixing boxes from double-duct to VAV; install variable frequency drives (VFD's) on supply and return fans.

**Summary of Ex Ante Impact Calculations** Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and all HVAC plant and system characteristics.

**Comments on PG&E Calculations** The correct climate zone and building characteristics were used in the application.

**Evaluation Process** The evaluation process consisted of reviewing the application form and supporting documentation. An on-site survey was attempted on September 29, 1999 in San Jose (Climate Zone 4). The contact was unable to provide access to any of the retrofit equipment. Future attempts at rescheduling the on-site were unsuccessful. Due to the difficulties associated with this site, a thorough review of the application was conducted. Ex ante impact estimates are accepted as accurate.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 542 | 2,976,298.27 | 89,512 |
| **Adjusted Engineering** | 542 | 2,976,298.27 | 89,512 |
| **Engineering Realization Rate** | 1.00 | 1.00 | 1.00 |

**Customized Space Conditioning (Site 245)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | Space Conditioning (Customized) |
| Site Description | Community Service |

**Measure Description** Replace pumps and motors for chilled water supply, hot water and boiler feed water; replace motors on two supply and return fans; replace all controls to DDC; install variable frequency drives (VFD's) on large motors, chiller, and cooling tower; replace mixing boxes from constant volume to variable air volume.

**Summary of Ex Ante Impact Calculations** Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and all HVAC plant and system characteristics.

**Comments on PG&E Calculations** The correct climate zone and building characteristics were used in the application.

**Evaluation Process** The evaluation process consisted of reviewing the application form and supporting documentation. An on-site survey was attempted on September 29, 1999 in San Jose (Climate Zone 4). The contact was unable to provide access to any of the retrofit equipment. Future attempts at rescheduling the on-site were unsuccessful. Due to the difficulties associated with this site, a thorough review of the application was conducted. Ex ante impact estimates are accepted as accurate.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 216 | 1,098,003.16 | 53,534 |
| **Adjusted Engineering** | 216 | 1,098,003.16 | 53,534 |
| **Engineering Realization Rate** | 1.00 | 1.00 | 1.00 |

**Convert HVAC System to VAV (Site 257)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | Convert HVAC system from CV to VAV |
| Site Description | Personal Service |

**Measure Description** Convert HVAC system from constant volume (CV) to variable air volume (VAV) by installing variable frequency drives (VFD's) on new, smaller supply fan motors.

**Summary of Ex Ante Impact Calculations** Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and all HVAC plant and system characteristics.

**Comments on PG&E Calculations** The correct climate zone and building characteristics were used in the application.

**Evaluation Process** The evaluation process consisted of reviewing the application form and supporting documentation. Due to security restrictions at this site, a thorough review of the application was conducted in lieu of an on-site audit. Ex ante impact estimates are accepted as accurate.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 99 | 1,529,262.17 | 0 |
| **Adjusted Engineering** | 99 | 1,529,262.17 | 0 |
| **Engineering Realization Rate** | 1.00 | 1.00 | N/A |

**Cooling Tower Replacement (Site 1278)**

| | |
|---|---|
| Program | Retrofit Efficiency Options Program |
| Measure | Oversized Evaporative Cooling Tower |
| Site Description | Health Care/Hospital |

**Measure Description** Replace Cooling tower with an oversized cooling tower.

**Summary of Ex Ante Impact Calculations** Tables of standard values were developed using the HBSSM simulation program based on climate zone, chiller size, building type, chiller efficiency, and condenser water temperature. Values from these tables are used to calculate the rebate and associated impacts.

**Comments on PG&E Calculations** The correct climate zone, approach temperature, fan horsepower per evaporator ton, and building type were used in the application.

**Evaluation Process** The evaluation process consisted of reviewing the application form and supporting documentation and conducting an on-site survey.

The on-site survey was conducted on September 15, 1999. Information on the retrofit equipment and operating conditions were collected through an inspection of the cooling tower and through an interview with the Chief Engineer. The on-site survey revealed that the site is in the middle of a chiller retrofit. The original 650-ton chiller, which was used in the rebate calculations, is no longer in place. The interview revealed that the old chiller operated very closely to the application claims, and the new chiller would operate very closely to that of the old chiller. Therefore, impacts claimed in the application are deemed reasonable and accepted as accurate.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 31.56 | 105,219.28 | 0 |
| **Adjusted Engineering** | 31.56 | 105,219.28 | 0 |
| **Engineering Realization Rate** | 1.0 | 1.0 | N/A |

**Chiller Replacement & VFD Installation (Site 1314)**

| | |
|---|---|
| Program | Retrofit Express Program |
| Measure | High Efficiency Air-Cooled Chiller and Variable Speed Drives |
| Site Description | Community Service |

**Measure Description** Replace existing chillers with two 50-ton high-efficiency air-cooled chillers and install two variable frequency drives (VFD's) on hvac fans.

**Summary of Ex Ante Impact Calculations** Impact calculations were performed separately for the chillers and the VFDs. For the water chiller, coincident demand savings is calculated by multiplying the measure demand savings by the coincident diversity factor. Annual energy impacts are calculated by multiplying the measure demand savings by the equivalent full load cooling hours. For the VFDs, energy impacts were calculated using an assumed 30 hp motor size to calculate a per-horsepower impact that is applied to all VFD's on motors 50 hp and less.

**Comments on PG&E Calculations** The application calculations used the correct chiller size, fan horsepower, and building characteristics.

**Evaluation Process** The evaluation process consists of a review of the application form and supporting documentation. After a thorough review of the application and rebate calculations, ex ante estimates are accepted as accurate.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 14.25 | 22,804.18 | 0 |
| **Adjusted Engineering** | 14.25 | 22,804.18 | 0 |
| **Engineering Realization Rate** | 1.00 | 1.00 | N/A |

**Evaporative Cooling (Site 1327)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | Install Evaporative Cooler |
| Site Description | Retail |

**Measure Description** Install a packaged evaporative cooler to provide cooling.

**Summary of Ex Ante Impact Calculations** Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and all HVAC plant and system characteristics.

**Comments on PG&E Calculations** The correct climate zone, plant characteristics and building were used in the application. The baseline equipment modeled was an air-cooled packaged unit with a capacity of 1169 kBtu/h, while the installed water-cooled unit has a capacity of 1390 kBtu/h.

**Evaluation Process** The evaluation process consisted of reviewing the application form and supporting documentation and conducting an on-site survey. The on-site survey was conducted on September 9, 1999 in San Francisco (Climate Zone 3). Information on the retrofit equipment and operating conditions were collected through an inspection of the plant and through an interview with the Chief Engineer. The Chief Engineer does not work on-site on a regular basis, and there is no means of tracking equipment usage.

Due to the fact that evaporative cooling is generally not specified for this climate zone, there is a lack of quality information regarding the performance in this area. DOE2 input files obtained from the consulting firm that prepared the documentation were verified for accuracy and executed again. Using inputs and outputs from the DOE2 files, the Equivalent Full Load Cooling Hours (EFLCH) and area served per ton of cooling were calculated. Results indicate that the baseline air-cooled unit is supplying approximately four times the EFLCH than estimated for standard packaged air-cooled AC units in the same climate zone. Without any documentation of equipment usage, the DOE2 results obtained from executing the input files is accepted as the ex post impact results, which are slightly higher than ex ante impact results for energy and much higher than ex ante for demand. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

Impact Results

| | KW | KWh | Therm |
|---|---|---|---|
| MDSS | 22 | 33,789.19 | 0 |
| Adjusted Engineering | 34.81 | 35,742 | 0 |
| Engineering Realization Rate | 1.58 | 1.06 | N/A |

Site 1327

| Results | Energy | Demand |
|---|---|---|
| MDSS | 33,789 | 22 |
| QC | 35,742 | 35 |
| Realization Rate | 1.06 | 1.58 |

| Parameters | Baseline Air-Cooled Unit | New Evap. Unit | Impact | Units | Source |
|---|---|---|---|---|---|
| Building Area | 37400.00 | 37400.00 | | sq. ft. | Application |
| Area/Ton | 383.92 | 322.88 | | sq. ft./ton | = Building Area (sq. ft.) / (Total Capacity (kBtuh) / 12 Btuh/ton) |
| Total Capacity | 1169.00 | 1390.00 | | kBtuh | DOE2 Input |
| Total Capacity | 97.42 | 115.83 | | Tons | = Total Capacity / 12 |
| Sensible Capacity | 858.00 | 1020.00 | | kBtuh | DOE2 Input |
| EER | 8.20 | 12.90 | | kBtuh/kW | DOE2 Input |
| Efficiency | 1.46 | 0.93 | | kW/ton | =12 kBtuh/ton / EER (kBtuh/kW) |
| Peak kW | 142.56 | 107.75 | 34.81 | kW | = Total Capacity (kBtuh) * Efficiency (kW/ton) / 12 kBtuh/ton |
| Total Electrical Cooling Input | 129702.00 | 93960.00 | 35742.00 | kWh | DOE2 Output 146242 and 108852 from application output |
| EFLCH | 909.80 | 872.00 | | Hours | = Total Electrical Cooling Input / Peak kW |
| MDSS Demand Impact | | | 22.00 | kW | |
| MDSS Energy Impact | | | 33789.19 | kWh | |
| Demand Realization Rate for Cooling Only | | | 1.58 | kW | = Peak kW Impact / MDSS Demand Impact |
| Energy Realization Rate for Cooling Only | | | 1.06 | kWh | |

**Valve Replacement (Site 1407)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | Three-way Chilled Water Control Valves |
| Site Description | Office |

**Measure Description** Install three-way chilled water control valves in all seven air handler cooling coils and install pneumatic control system to operate the three-way valves.

**Summary of Ex Ante Impact Calculations** Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and all HVAC plant and system characteristics.

**Comments on PG&E Calculations** The correct climate zone, chiller characteristics and building were used in the application.

**Evaluation Process** The evaluation process consisted of reviewing the application form and supporting documentation and conducting an on-site survey. The on-site survey was conducted on September 17, 1999 in San Francisco (Climate Zone 3). Information on the retrofit equipment and operating conditions were collected through an inspection of the plant and through an interview with the Mechanical Contractor that maintains the equipment.

The valves are installed in air handlers throughout the building, making it infeasible to visually inspect them. There is not an on-site building engineer or any other facilities person, so day-to-day operating characteristics were not available. Because of the lack of quality information available and the thorough review of the project in the application, impacts claimed in the application are deemed reasonable.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| MDSS | 3 | 39,345.21 | 11,399 |
| Adjusted Engineering | 3 | 39,345.21 | 11,399 |
| Engineering Realization Rate | 1.0 | 1.0 | 1.0 |

**Chiller Replacement (Site 1463)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | High Efficiency Water-Cooled Chiller |
| Site Description | Office |

**Measure Description**

Replace one of two existing chillers with a high-efficiency water-cooled chiller.

**Summary of Ex Ante Impact Calculations**

Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and all HVAC plant & system characteristics.

**Comments on PG&E Calculations**

The correct climate zone, chiller size category and building characteristics were used in the application calculations. However, the calibration to customer billing records appears to have vastly over-estimated the chiller contribution to those bills, resulting in a considerable over-estimation of impact. The most likely source of error is the hours of operation for the chillers.

**Evaluation Process**

The evaluation process consists of a review of the application form and supporting documentation, conducting an on-site survey and then computing impacts using the on-site data.

The on-site survey was conducted on July 27, 1999 in San Francisco (Climate Zone 3). Information on the retrofit equipment and operating conditions were collected through an inspection of the chiller and through an interview with the Chief Engineer.

Discussions provided data for development of a relationship between chiller loading and outdoor dry bulb. The chiller is available from 6:00 am to 4:20 pm on weekdays only. The chiller is manually controlled using operator discretion. The Chiller is generally brought on line at 65 degrees outside air temperature. The Chief Engineer estimated that the chiller reaches 100% loading at approximately 90 degrees outside air temperature. The secondary chiller operates only once per month for exercise.

Models are calibrated with actual weather, observed chiller run hours since the installation, the chiller lock-out temperature, chiller loading under extreme outdoor temperature conditions, chilled water temperature, and condenser water temperature. Energy impacts are based on typical weather data. A Title 24 baseline, nominal efficiency, and typical year bin weather data for the applicable climate zone are used in the bin analysis. To compute the impacts, the following assumptions were used:

- A linear loading strategy was used for the analysis of both the baseline and rebated chillers, which assumed initial loading at 65 degrees and 100% loading at 90 Degrees F.

- Based on a water-cooled chiller greater than 300 tons, a baseline Title 24 efficiency of 0.748 KW/ton was used.

Chiller efficiencies at various temperatures were calculated from updated default performance coefficients provided in a memo to the California Energy Commission titled "1995 Proposed Changes to the ACM Manual Central Plant Cooling Equipment" by Mark Hydeman. These coefficients were used to develop a chiller efficiency curve for the Rebate case and a Title 24 base case. Both evaluation-based demand and energy impacts were lower than Ex Ante estimates. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

**Impact Results**

| | **KW** | **KWh** | **Therm** |
|---|---|---|---|
| **MDSS** | 131 | 571,332.67 | 0 |
| **Adjusted Engineering** | 123.26 | 36,857.71 | 0 |
| **Engineering Realization Rate** | 0.94 | 0.06 | N/A |

Site 1463: Results

| | Impact | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 571,333 | 131 | | |
| QC | 36,857 | 123 | 36,993 | 144.28 |
| Realization Rate | 0.06 | 0.94 | | |

| Post-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.486 |
| Nom. Tons | 603 |
| nom kw | 293.058 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 92 | 0.71 | 603 | 0.38 | 163.27 | 228.57 | 4.33 | 990.48 |
| 87 | 19.52 | 503 | 0.37 | 3,644.43 | 186.67 | 35.67 | 6,657.76 |
| 82 | 39.52 | 402 | 0.37 | 5,884.44 | 148.88 | 71.33 | 10,620.35 |
| 77 | 113.57 | 302 | 0.38 | 13,068.61 | 115.07 | 105.00 | 12,082.30 |
| 72 | 252.38 | 201 | 0.42 | 21,470.83 | 85.07 | 162.00 | 13,781.84 |
| 67 | 410.48 | 101 | 0.58 | 24,114.01 | 58.75 | 348.00 | 20,443.76 |
| Totals | 836.19 | | 0.00 | 68,345.60 | 228.57 | 726.33 | 64,576.49 |

| Title 24 Baseline Chiller | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 603 |
| nom kw | 451.095 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 92 | 0.71 | 603 | 0.58 | 251.31 | 351.84 |
| 87 | 19.52 | 503 | 0.57 | 5,609.77 | 287.33 |
| 82 | 39.52 | 402 | 0.57 | 9,057.74 | 229.17 |
| 77 | 113.57 | 302 | 0.59 | 20,116.12 | 177.12 |
| 72 | 252.38 | 201 | 0.65 | 33,049.40 | 130.95 |
| 67 | 410.48 | 101 | 0.90 | 37,117.97 | 90.43 |
| Totals | 836.19 | | 0.00 | 105,202.31 | 351.84 |

| Pre-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.813 |
| Nom. Tons | 588 |
| nom kw | 478.044 |

| Outdoor DB Temperature (F) | Operating Hours per year (Actual) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 92 | 4.33 | 588 | 0.63 | 1,615.70 | 372.85 |
| 87 | 35.67 | 490 | 0.62 | 10,860.31 | 304.49 |
| 82 | 71.33 | 392 | 0.62 | 17,324.19 | 242.86 |
| 77 | 105.00 | 294 | 0.64 | 19,708.97 | 187.70 |
| 72 | 162.00 | 196 | 0.71 | 22,481.31 | 138.77 |
| 67 | 348.00 | 98 | 0.98 | 33,348.40 | 95.83 |
| Totals | 726.33 | | 0.00 | 105,338.89 | 372.85 |

Site 1463: Inputs to Model

| Parameter | Value Reported | Units of Parameter | Notes |
|---|---|---|---|
| City | San Francisco | | |
| Climate Zone | 3 | | |
| Pre-Retrofit Nominal Chiller Capacity | 588 | Tons | Application |
| Pre-Retrofit Nominal Chiller Efficiency | 0.813 | kW/ton | Application |
| | | | |
| Post-Retrofit Nominal Chiller Capacity | 620 | Tons | Application |
| Post-Retrofit Nominal Chiller Efficiency | 0.486 | kW/ton | From Chiller Rating Sheet |
| Post-Retrofit Chiller Full Load Amps | 441 | FLA | From York Manual |
| Post-Retrofit Chiller Max kW | 302 | kW | From York Manual |
| Baseline Chiller Efficiency | 0.748 | kW/ton | Title 24 Nominal Efficiency for Chiller > 300 Tons |
| | | | |
| Chiller AM Lockout | 6:00 | AM | Contact provided schedule; Chiller is on Manual Operation |
| Chiller PM Lockout | 16:20 | PM | Contact provided schedule; Chiller is on Manual Operation |
| Chiller Startup OSA Temperature | 65 | F | Contact provided estimate |
| Chiller Max Load OSA Temperature | 90 | F | Contact provided estimate |
| Chilled Water Supply Temperature Setpoint | 48 | F | Contact provided setpoints; Chiller is on Manual Operation |
| Condenser Water Temperature | 70 | F | Contact provided setpoints; Chiller is on Manual Operation |
| Date of Chiller Installation | 6/30/98 | | Contact provided estimate |
| Date at Run Hour Reading | 7/23/99 | | Chiller Log |
| Number of Days Chiller Operated | 267 | days (M-F Only) | = ((Read Date - Install Date) * 5/7) - 10 Holidays |
| Run Hours for New Chiller | 745 | hours | Documented from Chiller Log |
| Average Hours per Year of Chiller Operation | 727.07 | Hours/Year (M-F Only) | = (Run Hours for New Chiller / Number of Days Chiller Operated) * 365 Days/Year * 5/7 |
| | | | |
| Predicted Run Hours Since Install Using Actual Weather & Setpoints | 837.00 | hours | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |
| Predicted Hours per Year Using Actual Weather Data & Setpoints | 730.33 | Hours/Year (M-F Only) | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |

Site 1463: Post-Retrofit Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.486 |
| Nom. Tons | 603 |
| nom kw | 293.058 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 92 | 603 | 73 | 48 | 625 | 1.000 | 1.00 | 0.78 | 0.1078 | 9.28 | 0.379 |
| 87 | 503 | 72 | 48 | 624 | 0.833 | 0.83 | 0.77 | 0.1057 | 9.46 | 0.371 |
| 82 | 402 | 71 | 48 | 624 | 0.667 | 0.67 | 0.76 | 0.1053 | 9.49 | 0.370 |
| 77 | 302 | 70 | 48 | 623 | 0.500 | 0.52 | 0.75 | 0.1085 | 9.21 | 0.382 |
| 72 | 201 | 69 | 48 | 621 | 0.333 | 0.39 | 0.74 | 0.1204 | 8.31 | 0.423 |
| 67 | 101 | 68 | 48 | 619 | 0.167 | 0.28 | 0.73 | 0.1663 | 6.01 | 0.585 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1463: Baseline Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 603 |
| nom kw | 451.095319 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 92 | 603 | 73 | 48 | 625 | 1.000 | 1.00 | 0.78 | 0.1660 | 6.03 | 0.583 |
| 87 | 503 | 72 | 48 | 624 | 0.833 | 0.83 | 0.77 | 0.1626 | 6.15 | 0.572 |
| 82 | 402 | 71 | 48 | 624 | 0.667 | 0.67 | 0.76 | 0.1621 | 6.17 | 0.570 |
| 77 | 302 | 70 | 48 | 623 | 0.500 | 0.52 | 0.75 | 0.1671 | 5.98 | 0.587 |
| 72 | 201 | 69 | 48 | 621 | 0.333 | 0.39 | 0.74 | 0.1853 | 5.40 | 0.651 |
| 67 | 101 | 68 | 48 | 619 | 0.167 | 0.28 | 0.73 | 0.2559 | 3.91 | 0.900 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1463: Pre-Retrofit Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.813 |
| Nom. Tons | 588 |
| nom kw | 478.044 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 92 | 588 | 73 | 48 | 609 | 1.000 | 1.00 | 0.78 | 0.1804 | 5.54 | 0.634 |
| 87 | 490 | 72 | 48 | 609 | 0.833 | 0.83 | 0.77 | 0.1767 | 5.66 | 0.621 |
| 82 | 392 | 71 | 48 | 608 | 0.667 | 0.67 | 0.76 | 0.1762 | 5.68 | 0.620 |
| 77 | 294 | 70 | 48 | 607 | 0.500 | 0.52 | 0.75 | 0.1816 | 5.51 | 0.638 |
| 72 | 196 | 69 | 48 | 606 | 0.333 | 0.39 | 0.74 | 0.2014 | 4.97 | 0.708 |
| 67 | 98 | 68 | 48 | 604 | 0.167 | 0.28 | 0.73 | 0.2781 | 3.60 | 0.978 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1463: Weather Data

TMY temperature data for climate zone 3

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 0 | 0 | 1 | 4 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 37 | 6 | 9 | 13 | 13 | 16 | 15 | 18 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 6 | |
| 42 | 28 | 31 | 34 | 46 | 45 | 44 | 38 | 28 | 12 | 5 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 5 | 6 | 7 | 16 | 21 | 26 | |
| 47 | 72 | 77 | 79 | 84 | 71 | 66 | 70 | 65 | 43 | 31 | 12 | 8 | 6 | 3 | 2 | 2 | 2 | 6 | 21 | 32 | 44 | 43 | 48 | 54 | |
| 52 | 120 | 125 | 125 | 116 | 127 | 122 | 104 | 85 | 79 | 68 | 60 | 43 | 26 | 20 | 17 | 21 | 36 | 53 | 68 | 78 | 93 | 107 | 124 | 127 | |
| 57 | 116 | 105 | 100 | 90 | 95 | 106 | 112 | 120 | 104 | 89 | 83 | 79 | 68 | 70 | 80 | 79 | 95 | 108 | 115 | 129 | 129 | 137 | 127 | 125 | |
| 62 | 21 | 17 | 12 | 11 | 9 | 11 | 19 | 58 | 98 | 102 | 91 | 77 | 77 | 83 | 79 | 84 | 91 | 111 | 109 | 99 | 83 | 55 | 35 | 25 | |
| 67 | 2 | 0 | 1 | 1 | 1 | 1 | 3 | 5 | 20 | 56 | 74 | 77 | 72 | 78 | 84 | 78 | 83 | 60 | 38 | 19 | 9 | 4 | 5 | 2 | 574.67 |
| 72 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 9 | 32 | 51 | 64 | 61 | 58 | 57 | 37 | 19 | 9 | 2 | 0 | 0 | 0 | 0 | 353.33 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 10 | 21 | 31 | 30 | 28 | 28 | 15 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 159.00 |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 8 | 13 | 11 | 11 | 9 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 55.33 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 7 | 5 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 27.33 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| On Hours | | | | | | | 3 | 7 | 28 | 70 | 118 | 158 | 188 | 188 | 186 | 178 | 46.67 | | | | | | | | 836.19 |

Note: Total "On Hours" value has been scaled by 5/7 to account for M-F operation only

Actual temperature data for climate zone 3 for 7/24/98 to 7/23/99, M-F only

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 1 | 1 | 2 | 2 | 4 | 4 | 4 | 4 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 3 | |
| 37 | 7 | 9 | 8 | 9 | 10 | 9 | 13 | 10 | 5 | . | . | . | . | . | . | . | . | . | 1 | 2 | 3 | 3 | 4 | 3 | |
| 42 | 21 | 24 | 29 | 32 | 33 | 33 | 28 | 17 | 8 | 9 | 5 | 1 | 1 | . | . | . | 1 | 3 | 4 | 6 | 8 | 12 | 16 | 19 | |
| 47 | 46 | 46 | 46 | 43 | 45 | 44 | 40 | 42 | 38 | 25 | 17 | 14 | 10 | 11 | 8 | 7 | 9 | 15 | 19 | 28 | 37 | 37 | 39 | 44 | |
| 52 | 77 | 77 | 74 | 77 | 77 | 74 | 61 | 56 | 55 | 50 | 43 | 37 | 26 | 24 | 25 | 31 | 41 | 53 | 67 | 72 | 75 | 81 | 79 | 78 | |
| 57 | 66 | 66 | 71 | 69 | 66 | 70 | 75 | 70 | 64 | 63 | 63 | 56 | 57 | 59 | 63 | 62 | 69 | 74 | 81 | 80 | 78 | 74 | 71 | 64 | |
| 62 | 38 | 34 | 27 | 25 | 22 | 23 | 29 | 39 | 52 | 58 | 55 | 63 | 67 | 58 | 60 | 69 | 59 | 58 | 52 | 45 | 44 | 40 | 43 | 44 | |
| 67 | 3 | 3 | 3 | 4 | 4 | 4 | 7 | 15 | 22 | 28 | 41 | 42 | 43 | 48 | 47 | 42 | 39 | 24 | 20 | 18 | 12 | 12 | 7 | 5 | 348 |
| 72 | 2 | 1 | 1 | . | . | . | 4 | 6 | 11 | 17 | 14 | 20 | 24 | 25 | 19 | 16 | 18 | 19 | 12 | 8 | 3 | 2 | 1 | 1 | 162 |
| 77 | . | . | . | . | . | . | . | 2 | 4 | 7 | 15 | 17 | 14 | 13 | 16 | 13 | 12 | 11 | 3 | 2 | 1 | . | . | . | 105 |
| 82 | . | . | . | . | . | . | . | . | 2 | 4 | 6 | 5 | 10 | 13 | 14 | 14 | 10 | 2 | 2 | . | . | . | . | . | 71.33 |
| 87 | . | . | . | . | . | . | . | . | . | . | 2 | 6 | 7 | 8 | 7 | 5 | 2 | 2 | . | . | . | . | . | . | 35.67 |
| 92 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | 1 | 1 | . | . | . | . | . | . | . | 4.33 |
| 97 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | 1 | . | . | . | . | . | . | . | . | 4 |
| On Hours | | | | | | | 11 | 23 | 39 | 56 | 78 | 90 | 100 | 109 | 105 | 92 | 27.33 | | | | | | | | 730.33 |

Actual temperature data for climate zone 3 for 6/30/98 to 7/23/99, M-F only

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 1 | 1 | 2 | 2 | 4 | 4 | 4 | 4 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 3 | |
| 37 | 7 | 9 | 8 | 9 | 10 | 9 | 13 | 10 | 5 | . | . | . | . | . | . | . | . | . | 1 | 2 | 3 | 3 | 4 | 3 | |
| 42 | 21 | 24 | 29 | 32 | 33 | 33 | 28 | 17 | 8 | 9 | 5 | 1 | 1 | . | . | . | 1 | 3 | 4 | 6 | 8 | 12 | 16 | 19 | |
| 47 | 46 | 46 | 46 | 43 | 45 | 44 | 40 | 42 | 38 | 25 | 17 | 14 | 10 | 11 | 8 | 7 | 9 | 15 | 19 | 28 | 37 | 37 | 39 | 44 | |
| 52 | 77 | 77 | 74 | 77 | 77 | 74 | 61 | 56 | 55 | 50 | 43 | 37 | 26 | 24 | 25 | 31 | 41 | 53 | 67 | 72 | 75 | 81 | 79 | 78 | |
| 57 | 79 | 82 | 87 | 85 | 81 | 85 | 88 | 81 | 71 | 67 | 65 | 57 | 57 | 59 | 63 | 62 | 69 | 75 | 85 | 86 | 89 | 86 | 83 | 77 | |
| 62 | 42 | 36 | 29 | 27 | 25 | 26 | 32 | 43 | 59 | 64 | 61 | 67 | 70 | 60 | 62 | 72 | 63 | 66 | 61 | 55 | 50 | 45 | 48 | 48 | |
| 67 | 4 | 3 | 3 | 4 | 4 | 4 | 8 | 16 | 23 | 33 | 46 | 50 | 52 | 57 | 57 | 51 | 47 | 29 | 23 | 19 | 13 | 13 | 8 | 6 | 408.67 |
| 72 | 2 | 1 | 1 | . | . | . | 5 | 8 | 12 | 17 | 16 | 22 | 25 | 27 | 20 | 18 | 21 | 21 | 13 | 9 | 3 | 2 | 1 | 1 | 177.00 |
| 77 | . | . | . | . | . | . | . | 2 | 6 | 9 | 16 | 17 | 16 | 15 | 19 | 15 | 14 | 12 | 4 | 2 | 1 | . | . | . | 119.67 |
| 82 | . | . | . | . | . | . | . | . | 2 | 5 | 8 | 6 | 12 | 15 | 15 | 15 | 10 | 3 | 2 | . | . | . | . | . | 81.33 |
| 87 | . | . | . | . | . | . | . | . | . | . | 2 | 8 | 7 | 8 | 7 | 5 | 3 | 2 | . | . | . | . | . | . | 38.00 |
| 92 | . | . | . | . | . | . | . | . | . | . | . | . | 2 | 2 | 2 | 2 | 1 | . | . | . | . | . | . | . | 8.33 |
| 97 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | 1 | . | . | . | . | . | . | . | . | 4.00 |
| On Hours | | | | | | | 13 | 26 | 43 | 64 | 88 | 103 | 115 | 125 | 121 | 107 | 32 | | | | | | | | 837.00 |

**Chiller and Cooling Tower Replacement (Site 1841)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | High Efficiency Water-Cooled Chiller and Oversized Cooling Tower |
| Site Description | Office |

**Measure Description**

Replace existing 390-ton chiller with a 260-ton high-efficiency water-cooled chiller and replace cooling tower with an oversized cooling tower.

**Summary of Ex Ante Impact Calculations**

Impacts were developed using DOE2.1E simulation program based on climate zone, building type, chiller and cooling tower characteristics.

**Comments on PG&E Calculations**

The correct climate zone, chiller size category and building characteristics were used in the application calculations. However, the impact estimate provided in the MDSS is based on pre-retrofit conditions as opposed to baseline conditions. The condenser water temperature also appears to have been misrepresented.

**Evaluation Process**

The evaluation process consists of a review of the application form and supporting documentation, conducting an on-site survey and then computing impacts using the on-site data.

The on-site survey was conducted on July 19, 1999. Information on the retrofit equipment and operating conditions were collected through an on-site inspection of the chiller and cooling tower and through a telephone interview with the Control Systems company that is contracted to maintain the Energy Management System that is in place at the site. Trend logs for the HVAC system were also obtained.

Discussions provided data for development of a relationship between chiller loading and outdoor dry bulb. The HVAC system is available from 7:45 am to 8:00 pm every day. The chiller is controlled by an EMS, and is brought on line when the outside air temperature reaches 65 degrees F and any zone temperature is above 72 degrees F. 100% loading occurs at approximately 95 degrees outside air temperature.

Models are calibrated with actual weather, observed compressor run hours since the installation, the chiller lock-out hours and temperature, chiller loading under extreme outdoor temperature conditions, chilled water temperature, condenser water temperature, cooling tower approach temperature, and observations from HVAC trend logs. Energy impacts are based on typical weather data. A Title 24 baseline, nominal efficiency, typical year bin weather data for the applicable climate zone, and a chiller efficiency improvement of 0.01 kW/ton per degree of approach temperature reduction are used in the bin analysis. To compute the impacts, the following assumptions were used:

- A linear loading strategy was used for the analysis of both the baseline and rebated chillers, which assumed initial loading at 65 degrees and 100% loading at 95 Degrees F.

- For the baseline chiller case a Title 24 baseline efficiency of 0.837 KW/ton is used, based on a water-cooled chiller between 150 and 300 tons.

- An assumed chiller improvement of 0.01 KW/ton per degree reduction of approach temperature is used to quantify the impacts associated with the retrofit cooling tower.

Chiller efficiencies at various temperatures were calculated from updated default performance coefficients provided in a memo to the California Energy Commission titled "1995 Proposed Changes to the ACM Manual Central Plant Cooling Equipment" by Mark Hydeman. These coefficients were used to develop a chiller efficiency curve for the Rebate case and a Title 24 base case. Evaluation-based demand impacts were higher and energy impacts were lower than Ex Ante estimates. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 98 | 268,829.25 | 0 |
| **Adjusted Engineering** | 75.10 | 48,041.05 | 0 |
| **Engineering Realization Rate** | 0.77 | 0.18 | N/A |

Site 1841: Results for Chiller and Cooling Tower Retrofit

| | Impact | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 268,829.25 | 98.00 | | |
| QC | 48,041.05 | 75.10 | 68,174.62 | 168.88 |
| Realization Rate | 0.18 | 0.77 | | |

| Title 24 Baseline Chiller | |
|---|---|
| Nom. Eff | 0.837142857 |
| Nom. Tons | 260 |
| nom kw | 217.66 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 97 | 0.00 | 260 | 0.69 | 0.00 | 179.08 |
| 92 | 1.00 | 223 | 0.68 | 151.84 | 151.84 |
| 87 | 28.00 | 186 | 0.69 | 3583.17 | 127.97 |
| 82 | 58.00 | 149 | 0.72 | 6233.84 | 107.48 |
| 77 | 175.00 | 111 | 0.81 | 15814.02 | 90.37 |
| 72 | 406.50 | 74 | 1.03 | 31149.15 | 76.63 |
| 67 | 740.25 | 37 | 1.78 | 49053.02 | 66.27 |
| Totals | 1408.75 | | | 105985.04 | 179.08 |

| Post-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.496 |
| Nom. Tons | 260 |
| nom kw | 128.96 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) | Operating Hours per Year (Actual) | Actual Annual Energy Use (kWh/year) |
|---|---|---|---|---|---|---|---|
| 97 | 0.00 | 260 | 0.40 | 0.00 | 103.98 | 4.00 | 415.93 |
| 92 | 1.00 | 223 | 0.40 | 88.15 | 88.15 | 5.00 | 440.73 |
| 87 | 28.00 | 186 | 0.39 | 2046.54 | 73.09 | 34.00 | 2485.08 |
| 82 | 58.00 | 149 | 0.41 | 3564.06 | 61.45 | 78.00 | 4793.04 |
| 77 | 175.00 | 111 | 0.46 | 8917.15 | 50.96 | 126.50 | 6445.83 |
| 72 | 406.50 | 74 | 0.58 | 17634.18 | 43.38 | 203.25 | 8817.09 |
| 67 | 740.25 | 37 | 1.00 | 27518.56 | 37.17 | 420.75 | 15641.25 |
| Totals | 1408.75 | | | 59768.63 | 103.98 | 867.5 | 39038.95 |

| Pre-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.85 |
| Nom. Tons | 390 |
| nom kw | 331.5 |

| Outdoor DB Temperature (F) | Operating Hours per year (Actual) | Tons Output | Efficiency (kW/Ton) | Actual Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 97 | 4.00 | 390 | 0.70 | 1091.45 | 272.86 |
| 92 | 5.00 | 334 | 0.69 | 1156.78 | 231.36 |
| 87 | 34.00 | 279 | 0.70 | 6629.62 | 194.99 |
| 82 | 78.00 | 223 | 0.73 | 12773.64 | 163.76 |
| 77 | 126.50 | 167 | 0.82 | 17416.76 | 137.68 |
| 72 | 203.25 | 111 | 1.05 | 23727.62 | 116.74 |
| 67 | 420.75 | 56 | 1.81 | 42471.32 | 100.94 |
| Totals | 867.5 | | | 105267.19 | 272.86 |

Site 1841: Results for Chiller Retrofit Only

| | Impact | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 268,829.25 | 98.00 | | |
| QC | 46,216.41 | 75.10 | 66877.03 | 171.48 |
| Realization Rate | 0.17 | 0.77 | | |

| Title 24 Baseline Chiller | |
|---|---|
| Nom. Eff | 0.837142857 |
| Nom. Tons | 260 |
| nom kw | 217.66 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 97 | 0.00 | 260 | 0.71 | 0.00 | 184.28 |
| 92 | 1.00 | 223 | 0.70 | 156.29 | 156.29 |
| 87 | 28.00 | 186 | 0.71 | 3687.17 | 131.68 |
| 82 | 58.00 | 149 | 0.74 | 6406.18 | 110.45 |
| 77 | 175.00 | 111 | 0.83 | 16204.02 | 92.59 |
| 72 | 406.50 | 74 | 1.05 | 31753.09 | 78.11 |
| 67 | 740.25 | 37 | 1.80 | 49602.92 | 67.01 |
| Totals | 1408.75 | | | 107809.68 | 184.28 |

| Post-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.496 |
| Nom. Tons | 260 |
| nom kw | 128.96 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) | Operating Hours per Year (Actual) | Actual Annual Energy Use (kWh/year) |
|---|---|---|---|---|---|---|---|
| 97 | 0.00 | 260 | 0.42 | 0.00 | 109.18 | 4.00 | 436.73 |
| 92 | 1.00 | 223 | 0.42 | 92.60 | 92.60 | 5.00 | 463.01 |
| 87 | 28.00 | 186 | 0.41 | 2150.54 | 76.80 | 34.00 | 2611.37 |
| 82 | 58.00 | 149 | 0.43 | 3736.40 | 64.42 | 78.00 | 5024.82 |
| 77 | 175.00 | 111 | 0.48 | 9307.15 | 53.18 | 126.50 | 6727.74 |
| 72 | 406.50 | 74 | 0.60 | 18238.12 | 44.87 | 203.25 | 9119.06 |
| 67 | 740.25 | 37 | 1.02 | 28068.46 | 37.92 | 420.75 | 15953.80 |
| Totals | 1408.75 | | | 61593.27 | 109.18 | 867.5 | 40336.53 |

| Pre-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.85 |
| Nom. Tons | 390 |
| nom kw | 331.5 |

| Outdoor DB Temperature (F) | Operating Hours per year (Actual) | Tons Output | Efficiency (kW/Ton) | Actual Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 97 | 4.00 | 390 | 0.72 | 1122.65 | 280.66 |
| 92 | 5.00 | 334 | 0.71 | 1190.20 | 238.04 |
| 87 | 34.00 | 279 | 0.72 | 6819.05 | 200.56 |
| 82 | 78.00 | 223 | 0.75 | 13121.29 | 168.22 |
| 77 | 126.50 | 167 | 0.84 | 17839.63 | 141.02 |
| 72 | 203.25 | 111 | 1.07 | 24180.58 | 118.97 |
| 67 | 420.75 | 56 | 1.83 | 42940.15 | 102.06 |
| Totals | 867.5 | | | 107213.57 | 280.66 |

Site 1841: Inputs to Model

| Parameter | Value | Units | Source |
|---|---|---|---|
| Building Location | San Francisco | | |
| Climate Zone | 3 | | |
| | | | |
| Pre-Retrofit Nominal Chiller Capacity | 390 | Tons | From Application |
| Pre-Retrofit Nominal Chiller Efficiency | 0.85 | kW/ton | From Application |
| Pre-Retrofit Cooling Tower Approach Temperature | 12 | F | From Application |
| | | | |
| Post-Retrofit Nominal Chiller Tons | 260 | tons | From Application |
| Post-Retrofit Nominal Chiller Efficiency | 0.496 | kW/ton | Norman Wright Mechanical Equipment Corp |
| Title 24 Chiller Efficiency | 0.837142857 | kW/ton | From Chiller Performance Curves |
| Post-Retrofit Cooling Tower Approach Temperature | 10 | F | From Application |
| | | | |
| Chiller AM Lockout | 7:45 | AM | EMS Contractor |
| Chiller PM Lockout | 8:00 | PM | EMS Contractor |
| Chiller Startup OSA Temperature | 64 | F | EMS Contractor |
| Chiller Max Load OSA Temperature | 95 | F | Contact provided estimate |
| Chilled Water Supply Temperature Setpoint | 44 | F | Chiller Display |
| Condenser Water Temperature Setpoint | 75 | F | Norman Wright Mechanical Equipment Corp |
| Date of Chiller Installation | 5/15/97 | | Comm-Air |
| Date at Run Hour Reading | 7/19/99 | | |
| Number of Days Chiller Operated | 795 | Days | Calculated |
| Run Hours for New Chiller | 2119 | Hours | Chiller Display |
| Average Hours per Year of Chiller Operation | 972.87 | Hours/Year | Calculated from Observed Operating Conditions |
| | | | |
| Run Hours Since Install Using Actual Weather & Setpoints | 2487.00 | Hours | Based on schedule and setpoints provided in interview and actual weather data |
| Hours per Year from Actual Weather Data | 871.50 | Hours/Year | Based on schedule and setpoints provided in interview and actual weather data |

Site 1841: Post-Retrofit Chiller

| Screw Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

| | |
|---|---|
| Nom. Eff | 0.496 |
| Nom. Tons | 260 |
| nom kw | 128.96 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 97 | 260 | 75 | 45 | 279 | 1.000 | 1.026 | 0.825 | 0.1194 | 8.37 | 0.420 |
| 92 | 223 | 75 | 45 | 279 | 0.857 | 0.87 | 0.82 | 0.1182 | 8.46 | 0.416 |
| 87 | 186 | 74 | 45 | 280 | 0.714 | 0.73 | 0.81 | 0.1176 | 8.50 | 0.414 |
| 82 | 149 | 74 | 45 | 280 | 0.571 | 0.62 | 0.81 | 0.1233 | 8.11 | 0.434 |
| 77 | 111 | 73 | 45 | 281 | 0.429 | 0.52 | 0.80 | 0.1357 | 7.37 | 0.477 |
| 72 | 74 | 73 | 45 | 281 | 0.286 | 0.44 | 0.80 | 0.1718 | 5.82 | 0.604 |
| 67 | 37 | 72 | 45 | 283 | 0.143 | 0.37 | 0.79 | 0.2903 | 3.44 | 1.021 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625 | 0.00069 | 0.00028 | -0.00342 | 0.00025 | -0.00048 |
| EIRFPLR | 0.33019 | 0.23554 | 0.46071 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1841: Baseline Chiller

| Screw Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

| | |
|---|---|
| Nom. Eff | 0.837 |
| Nom. Tons | 260 |
| nom kw | 217.66 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 97 | 260 | 75 | 45 | 279 | 1.000 | 1.026 | 0.825 | 0.2016 | 4.96 | 0.709 |
| 92 | 223 | 75 | 45 | 279 | 0.857 | 0.87 | 0.82 | 0.1995 | 5.01 | 0.701 |
| 87 | 186 | 75 | 45 | 279 | 0.714 | 0.73 | 0.82 | 0.2017 | 4.96 | 0.709 |
| 82 | 149 | 75 | 45 | 279 | 0.571 | 0.62 | 0.82 | 0.2114 | 4.73 | 0.743 |
| 77 | 111 | 75 | 45 | 279 | 0.429 | 0.52 | 0.82 | 0.2363 | 4.23 | 0.831 |
| 72 | 74 | 75 | 45 | 279 | 0.286 | 0.44 | 0.82 | 0.2991 | 3.34 | 1.052 |
| 67 | 37 | 75 | 45 | 279 | 0.143 | 0.37 | 0.82 | 0.5131 | 1.95 | 1.804 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625 | 0.00069 | 0.00028 | -0.00342 | 0.00025 | -0.00048 |
| EIRFPLR | 0.33019 | 0.23554 | 0.46071 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1841: Pre-Retrofit Chiller

| Screw Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

| | |
|---|---|
| Nom. Eff | 0.85 |
| Nom. Tons | 390 |
| nom kw | 331.5 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 97 | 390 | 75 | 45 | 418 | 1.000 | 1.026 | 0.825 | 0.2047 | 4.89 | 0.720 |
| 92 | 334 | 75 | 45 | 418 | 0.857 | 0.87 | 0.82 | 0.2025 | 4.94 | 0.712 |
| 87 | 279 | 75 | 45 | 418 | 0.714 | 0.73 | 0.82 | 0.2048 | 4.88 | 0.720 |
| 82 | 223 | 75 | 45 | 418 | 0.571 | 0.62 | 0.82 | 0.2147 | 4.66 | 0.755 |
| 77 | 167 | 75 | 45 | 418 | 0.429 | 0.52 | 0.82 | 0.2400 | 4.17 | 0.844 |
| 72 | 111 | 75 | 45 | 418 | 0.286 | 0.44 | 0.82 | 0.3037 | 3.29 | 1.068 |
| 67 | 56 | 75 | 45 | 418 | 0.143 | 0.37 | 0.82 | 0.5210 | 1.92 | 1.832 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625 | 0.00069 | 0.00028 | -0.00342 | 0.00025 | -0.00048 |
| EIRFPLR | 0.33019 | 0.23554 | 0.46071 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1841: Weather Data

TMY temperature data

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 0 | 0 | 1 | 4 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 37 | 6 | 9 | 13 | 13 | 16 | 15 | 18 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 6 | |
| 42 | 28 | 31 | 34 | 46 | 45 | 44 | 38 | 28 | 12 | 5 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 5 | 6 | 7 | 16 | 21 | 26 | |
| 47 | 72 | 77 | 79 | 84 | 71 | 66 | 70 | 65 | 43 | 31 | 12 | 8 | 6 | 3 | 2 | 2 | 2 | 6 | 21 | 32 | 44 | 43 | 48 | 54 | |
| 52 | 120 | 125 | 125 | 116 | 127 | 122 | 104 | 85 | 79 | 68 | 60 | 43 | 26 | 20 | 17 | 21 | 36 | 53 | 68 | 78 | 93 | 107 | 124 | 127 | |
| 57 | 116 | 105 | 100 | 90 | 95 | 106 | 112 | 120 | 104 | 89 | 83 | 79 | 68 | 70 | 80 | 79 | 95 | 108 | 115 | 129 | 129 | 137 | 127 | 125 | |
| 62 | 21 | 17 | 12 | 11 | 9 | 11 | 19 | 58 | 98 | 102 | 91 | 77 | 77 | 83 | 79 | 84 | 91 | 111 | 109 | 99 | 83 | 55 | 35 | 25 | |
| 67 | 2 | 0 | 1 | 1 | 1 | 1 | 3 | 5 | 20 | 56 | 74 | 77 | 72 | 78 | 84 | 78 | 83 | 60 | 38 | 19 | 9 | 4 | 5 | 2 | 740.25 |
| 72 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 9 | 32 | 51 | 64 | 61 | 58 | 57 | 37 | 19 | 9 | 2 | 0 | 0 | 0 | 0 | 406.5 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 10 | 21 | 31 | 30 | 28 | 28 | 15 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 175 |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 8 | 13 | 11 | 11 | 9 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 58 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 7 | 5 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| On Hours | | | | | | | | 1.75 | 28 | 70 | 118 | 158 | 188 | 188 | 186 | 178 | 140 | 85 | 47 | 21 | | | | | 1408.75 |

Actual temperature by hour from 07/20/98 to 07/19/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | |
| 37 | 6 | 8 | 7 | 8 | 10 | 9 | 13 | 10 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 3 | 2 | 1 | |
| 42 | 21 | 24 | 29 | 32 | 33 | 33 | 28 | 17 | 8 | 8 | 4 | 1 | 1 | 0 | 0 | 0 | 1 | 3 | 3 | 4 | 6 | 10 | 16 | 19 | |
| 47 | 45 | 45 | 45 | 43 | 44 | 43 | 40 | 42 | 38 | 24 | 16 | 12 | 9 | 10 | 7 | 6 | 8 | 13 | 18 | 28 | 37 | 37 | 39 | 44 | |
| 52 | 77 | 77 | 74 | 75 | 76 | 73 | 59 | 54 | 54 | 50 | 43 | 37 | 25 | 23 | 24 | 30 | 39 | 52 | 66 | 71 | 74 | 80 | 78 | 77 | |
| 57 | 63 | 64 | 69 | 68 | 65 | 69 | 75 | 70 | 61 | 62 | 62 | 55 | 56 | 58 | 62 | 61 | 68 | 73 | 80 | 78 | 76 | 72 | 70 | 63 | |
| 62 | 40 | 35 | 28 | 26 | 23 | 24 | 29 | 39 | 54 | 55 | 54 | 62 | 67 | 57 | 59 | 68 | 57 | 57 | 52 | 46 | 45 | 41 | 43 | 43 | |
| 67 | 3 | 3 | 3 | 3 | 3 | 3 | 7 | 15 | 22 | 30 | 41 | 42 | 42 | 47 | 47 | 42 | 41 | 25 | 20 | 18 | 11 | 11 | 6 | 5 | 420.75 |
| 72 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 11 | 17 | 14 | 20 | 24 | 26 | 19 | 16 | 18 | 19 | 11 | 7 | 3 | 2 | 1 | 1 | 203.25 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 7 | 15 | 17 | 14 | 13 | 16 | 13 | 12 | 10 | 3 | 2 | 1 | 0 | 0 | 0 | 126.5 |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 5 | 5 | 10 | 13 | 14 | 14 | 9 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 78 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 6 | 7 | 6 | 4 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 34 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| On Hours | | | | | | | | 5.5 | 38 | 57 | 77 | 89 | 98 | 108 | 104 | 91 | 83 | 58 | 36 | 27 | | | | | 871.50 |

Actual temperature by hour from 05/15/97 to 07/19/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | |
| 37 | 6 | 9 | 9 | 10 | 13 | 12 | 16 | 13 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 3 | 2 | 1 | |
| 42 | 30 | 35 | 40 | 47 | 52 | 49 | 44 | 25 | 10 | 9 | 4 | 1 | 1 | 0 | 0 | 0 | 1 | 3 | 3 | 4 | 8 | 13 | 19 | 25 | |
| 47 | 77 | 77 | 80 | 77 | 76 | 77 | 76 | 71 | 61 | 30 | 21 | 15 | 11 | 13 | 10 | 8 | 10 | 18 | 27 | 40 | 53 | 60 | 65 | 72 | |
| 52 | 134 | 142 | 139 | 142 | 142 | 145 | 116 | 103 | 97 | 93 | 73 | 58 | 41 | 36 | 37 | 46 | 66 | 90 | 113 | 124 | 127 | 128 | 133 | 137 | |
| 57 | 175 | 173 | 178 | 178 | 175 | 168 | 159 | 146 | 129 | 127 | 120 | 107 | 99 | 100 | 111 | 109 | 127 | 141 | 161 | 168 | 177 | 184 | 173 | 172 | |
| 62 | 111 | 102 | 88 | 83 | 82 | 86 | 96 | 107 | 120 | 113 | 113 | 122 | 135 | 124 | 117 | 139 | 123 | 117 | 120 | 124 | 121 | 114 | 124 | 114 | |
| 67 | 16 | 13 | 16 | 13 | 9 | 12 | 37 | 62 | 72 | 86 | 89 | 92 | 86 | 90 | 97 | 87 | 87 | 83 | 83 | 66 | 52 | 43 | 31 | 25 | 1033.5 |
| 72 | 2 | 0 | 0 | 0 | 0 | 0 | 5 | 19 | 46 | 60 | 64 | 66 | 68 | 74 | 66 | 66 | 75 | 61 | 26 | 17 | 7 | 4 | 3 | 2 | 693.75 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 11 | 25 | 47 | 56 | 61 | 55 | 60 | 52 | 37 | 25 | 12 | 5 | 2 | 2 | 0 | . | 446.75 |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 15 | 21 | 30 | 38 | 33 | 29 | 18 | 10 | 4 | 1 | 1 | 0 | 0 | . | 208 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 13 | 13 | 15 | 14 | 9 | 5 | 2 | 1 | 0 | 0 | 0 | 0 | . | 78 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 4 | 4 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | . | 21 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | . | 6 |
| On Hours | | | | | | | | 21 | 131 | 179 | 220 | 248 | 264 | 278 | 276 | 249 | 224 | 182 | 126 | 89 | | | | | 2487.00 |

**Chiller Replacement and Heat Exchanger Installation (Site 1909)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | High Efficiency Water-Cooled Chillers and Heat Exchanger |
| Site Description | Office |

**Measure Description**

Replace 2 existing 150-ton chillers and 2 existing 500-ton chillers with high efficiency units and add a plate-frame heat exchanger to utilize free cooling when available.

**Summary of Ex Ante Impact Calculations**

Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and chiller characteristics.

**Comments on PG&E Calculations**

The correct climate zone, chiller size category and building characteristics were used in the application calculations. There was not sufficient documentation to verify the heat exchanger characteristics, but the results seem to be consistent with the installed equipment. The application appears to have over-estimated the usage of the post-retrofit chillers, resulting in a modest over-estimation of impact. The most likely source of error is the loading and staging strategy for the heat exchanger and chillers.

**Evaluation Process**

The evaluation process consists of a review of the application form and supporting documentation, conducting an on-site survey and then computing impacts using the on-site data.

The on-site survey was conducted on June 24, 1999 in San Francisco (Climate Zone 3). Information on the retrofit equipment and operating conditions was collected through an inspection of the chillers and heat exchanger and through an interview with both the Lead Project Engineer and the Chief Building Engineer.

The trend logs from the EMS provided data for development of a relationship between chiller loading and outdoor dry bulb. The staging strategy for the plant provided by the contact varied from the data provided in the EMS trend logs. Stage 1 consists of the plate-frame heat exchanger. The trend logs indicate that the heat exchanger operates 24 hours per day on weekends and holidays and from 6:00 pm to 6:00 am on weekdays. There was no evidence of heat exchanger operation during business hours. Stage 2 is suppose to bring one 150-ton chiller online and utilizes the heat exchanger as a pre-cooler. This stage was not observed from the trend logs. Stage 3 brings both 150-ton chiller online, and uses the heat exchanger as a pre-cooler when ambient conditions are appropriate. Stage 4 shuts down the 150-ton chillers and the heat exchanger and brings one 500-ton chiller online. The contacts claim to have never passed this point and the EMS trend logs support this claim.

Models are calibrated with actual weather, EMS trend logs supplied by the contact, observed chiller run hours since the installation, chiller staging strategy supplied by the contact, chilled water temperatures, and condenser water temperatures. Energy impacts are based on typical weather data. A Title 24 baseline, nominal efficiency, and typical year bin weather data for the applicable climate zone are used in the bin analysis. To compute the impacts, the following assumptions were used:

- The baseline for the heat exchanger is a 150-ton Title-24 water-cooled centrifugal chiller; identical to the two 150-ton chillers modeled.

- A baseline Title 24 efficiency of 0.837 kW/ton was used for the 150-ton centrifugal chillers and heat exchanger and a baseline Title 24 efficiency of 0.748 KW/ton was used for the 500-ton centrifugal chillers.

Chiller efficiencies at various temperatures were calculated from updated default performance coefficients provided in a memo to the California Energy Commission titled "1995 Proposed Changes to the ACM Manual Central Plant Cooling Equipment" by Mark Hydeman. These coefficients were used to develop a chiller efficiency curve for the Rebate case and a Title 24 base case. Both evaluation-based demand and energy impacts were lower than Ex Ante estimates. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 80.00 | 483,304.54 | 0 |
| **Adjusted Engineering** | 46.25 | 424,813.49 | 0 |
| **Engineering Realization Rate** | 0.58 | 0.88 | N/A |

Site 1909: Results Summary

| | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 483,305 | 80 | | |
| QC | 424,813 | 46 | 658,808 | 147 |
| Realization Rate | 0.88 | 0.58 | | |

| Chiller #1 | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 483,305 | 80 | | |
| QC | 0 | 0 | 0 | 0 |
| Realization Rate | 0.00 | 0.00 | | |

| Chiller #2 | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 483,305 | 80 | | |
| QC | 7,571 | 46 | 24,126 | 147 |
| Realization Rate | 0.02 | 0.58 | | |

| Chiller #3 & #4 | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 483,305 | 80 | | |
| QC | 127,595 | 61 | 254,088 | 123 |
| Realization Rate | 0.26 | 0.76 | | |

| Heat Exchanger | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 483,305 | 80 | | |
| QC | 289,647 | 67 | 380,594 | 88 |
| Realization Rate | 0.60 | 0.83 | | |

Site 1909: Inputs to Model

| Parameter | Value Reported | Units of Parameter | Notes |
|---|---|---|---|
| City | San Francisco | | |
| Climate Zone | 3 | | |
| | | | |
| Chiller #1 Pre-Retrofit Nominal Capacity | 500 | Tons | Application |
| Chiller #1 Pre-Retrofit Nominal Efficiency | 1.05 | kW/ton | Application |
| Chiller #1 Post-Retrofit Nominal Capacity | 500 | Tons | Application |
| Chiller #1 Post-Retrofit Nominal Efficiency | 0.61 | kW/ton | Application |
| Chiller #1 Baseline Efficiency | 0.748 | kW/ton | Title 24 Nominal Efficiency for Chiller > 300 Tons |
| | | | |
| Chiller #2 Pre-Retrofit Nominal Capacity | 500 | Tons | Application |
| Chiller #2 Pre-Retrofit Nominal Efficiency | 1.05 | kW/ton | Application |
| Chiller #2 Post-Retrofit Nominal Capacity | 500 | Tons | Application |
| Chiller #2 Post-Retrofit Nominal Efficiency | 0.61 | kW/ton | Application |
| Chiller #2 Baseline Efficiency | 0.748 | kW/ton | Title 24 Nominal Efficiency for Chiller > 300 Tons |
| | | | |
| Chiller #3 Pre-Retrofit Nominal Capacity | 150 | Tons | Application |
| Chiller #3 Pre-Retrofit Nominal Efficiency | 1.1 | kW/ton | Application |
| Chiller #3 Post-Retrofit Nominal Capacity | 150 | Tons | Application |
| Chiller #3 Post-Retrofit Nominal Efficiency | 0.58 | kW/ton | Application |
| Chiller #3 Baseline Efficiency | 0.837 | kW/ton | Title 24 Nominal Efficiency for Chiller > 300 Tons |
| | | | |
| Chiller #4 Pre-Retrofit Nominal Capacity | 150 | Tons | Application |
| Chiller #4 Pre-Retrofit Nominal Efficiency | 1.1 | kW/ton | Application |
| Chiller #4 Post-Retrofit Nominal Capacity | 150 | Tons | Application |
| Chiller #4 Post-Retrofit Nominal Efficiency | 0.58 | kW/ton | Application |
| Chiller #4 Baseline Efficiency | 0.837 | kW/ton | Title 24 Nominal Efficiency for Chiller > 300 Tons |
| | | | |
| Post-Retrofit Heat Exchanger Capacity | 150 | Tons | Application |
| Heat Exchanger Pre-Retrofit Chiller Nominal Capacity | 150 | Tons | Application |
| Heat Exchanger Pre-Retrofit Chiller Nominal Efficiency | 1.1 | kW/ton | Application |
| Baseline Chiller Efficiency | 0.837 | kW/ton | Title 24 Nominal Efficiency for Chiller > 300 Tons |
| | | | |
| Chiller AM Lockout | 6:00 | AM | Contact provided schedule; Inverse schedule for Heat Exchanger |
| Chiller PM Lockout | 18:00 | PM | Contact provided schedule; Inverse schedule for Heat Exchanger |
| Chiller Startup OSA Temperature | 55 | F | Contact provided estimate |
| Date of Chiller Installation | 7/15/97 | | Contact provided estimate |
| Date at Run Hour Reading | 6/24/99 | | Chiller Log |
| Number of Days Chiller Operated | 486 | days (M-F Only) | = ((Read Date - Install Date) * 5/7) - 20 Holidays |
| Run Hours for Chiller #1 | 1531 | hours | Documented from Chiller Log |
| Run Hours for Chiller #2 | 1389 | hours | Documented from Chiller Log |
| Run Hours for Chiller #3 | 7758 | hours | Documented from Chiller Log |
| Run Hours for Chiller #4 | UTD | hours | |

Site 1909: Results for Chiller #1

| | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 483,305 | 80 | | |
| QC | 0 | 0 | 0 | 0 |
| Realization Rate | 0.00 | 0.00 | | |

| Post-Retrofit Chiller #1 | |
|---|---|
| Nom. Eff | 0.61 |
| Nom. Tons | 500 |
| nom kw | 305 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 102 | 0.00 | 400 | 0.536 | 0.00 | 0.00 | 0.00 | 0.00 |
| Totals | 0.00 | | | 0.00 | 0.00 | 0.00 | 0.00 |

| Title 24 Baseline Chiller #1 | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 500 |
| nom kw | 374.043 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 102 | 0.00 | 400 | 0.657 | 0.00 | 0.00 |
| Totals | 0.00 | | | 0.00 | 0.00 |

| Pre-Retrofit Chiller #1 | |
|---|---|
| Nom. Eff | 1.050 |
| Nom. Tons | 500 |
| nom kw | 525 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 102 | 0.00 | 400 | 0.922 | 0.00 | 0.00 | 0.00 | 0.00 |
| Totals | 0.00 | | | 0.00 | 0.00 | 0.00 | 0.00 |

Site 1909: Results for Chiller #2

| | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 483,305 | 80 | | |
| QC | 7,571 | 46 | 24,126 | 147 |
| Realization Rate | 0.02 | 0.58 | | |

| Post-Retrofit Chiller #2 | |
|---|---|
| Nom. Eff | 0.61 |
| Nom. Tons | 500 |
| nom kw | 305 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 97 | 0.00 | 380 | 0.537 | 0.00 | 204.30 | 0.00 | 0.00 |
| 92 | 0.71 | 361 | 0.547 | 140.97 | 197.36 | 1.00 | 197.36 |
| 87 | 20.00 | 341 | 0.559 | 3,804.53 | 190.23 | 16.00 | 3,043.63 |
| 82 | 41.43 | 321 | 0.571 | 7,577.54 | 182.91 | 66.00 | 12,071.80 |
| 77 | 125.00 | 301 | 0.584 | 21,923.73 | 175.39 | 168.00 | 29,465.49 |
| Totals | 187.14 | | | 33,446.77 | 204.30 | 251.00 | 44,778.28 |

| Title 24 Baseline Chiller #2 | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 500 |
| nom kw | 374 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 97 | 0.00 | 380 | 0.658 | 0.00 | 250.55 |
| 92 | 0.71 | 361 | 0.671 | 172.88 | 242.03 |
| 87 | 20.00 | 341 | 0.685 | 4,665.76 | 233.29 |
| 82 | 41.43 | 321 | 0.700 | 9,292.86 | 224.31 |
| 77 | 125.00 | 301 | 0.716 | 26,886.58 | 215.09 |
| Totals | 187.14 | | | 41,018.08 | 250.55 |

| Pre-Retrofit Chiller #2 | |
|---|---|
| Nom. Eff | 1.050 |
| Nom. Tons | 500 |
| nom kw | 525 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 97 | 0.00 | 380 | 0.924 | 0.00 | 351.67 | 0.00 | 0.00 |
| 92 | 0.71 | 361 | 0.942 | 242.65 | 339.71 | 1.00 | 339.71 |
| 87 | 20.00 | 341 | 0.962 | 6,548.79 | 327.44 | 16.00 | 5,239.03 |
| 82 | 41.43 | 321 | 0.982 | 13,043.30 | 314.84 | 66.00 | 20,779.33 |
| 77 | 125.00 | 301 | 1.005 | 37,737.56 | 301.90 | 168.00 | 50,719.29 |
| Totals | 187.14 | | | 57,572.31 | 351.67 | 251.00 | 77,077.36 |

Site 1909: Results for Chiller #3 & #4

| | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 483,305 | 80 | | |
| QC | 127,595 | 61 | 254,088 | 123 |
| Realization Rate | 0.26 | 0.76 | | |

| Post-Retrofit Chiller #3 & #4 | |
|---|---|
| Nom. Eff | 0.58 |
| Nom. Tons | 300 |
| nom kw | 174 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 72 | 283.57 | 281 | 0.491 | 39,020.03 | 137.60 | 263.00 | 36,189.35 |
| 67 | 492.86 | 261 | 0.506 | 64,946.18 | 131.77 | 883.00 | 116,357.20 |
| 62 | 692.86 | 241 | 0.522 | 87,020.77 | 125.60 | 1,717.00 | 215,650.02 |
| 57 | 776.43 | 221 | 0.540 | 92,419.11 | 119.03 | 2,029.00 | 241,514.01 |
| Totals | 2,245.71 | | | 283,406.08 | 137.60 | 4,892.00 | 609,710.57 |

| Title 24 Baseline Chiller #3 & #4 | |
|---|---|
| Nom. Eff | 0.837 |
| Nom. Tons | 300 |
| nom kw | 251.1428571 |

| Pre-Retrofit Chiller #3 & #4 | |
|---|---|
| Nom. Eff | 0.57 |
| Nom. Tons | 300 |
| nom kw | 171 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 72 | 283.57 | 281 | 0.709 | 56,373.31 | 198.80 |
| 67 | 492.86 | 261 | 0.730 | 93,740.35 | 190.20 |
| 62 | 692.86 | 241 | 0.756 | 125,932.61 | 181.76 |
| 57 | 776.43 | 221 | 0.788 | 134,954.88 | 173.81 |
| Totals | 2,245.71 | | | 411,001.14 | 198.80 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 72 | 283.57 | 281 | 0.930 | 74,003.50 | 260.97 | 263.00 | 68,634.98 |
| 67 | 492.86 | 261 | 0.959 | 123,173.79 | 249.92 | 883.00 | 220,677.44 |
| 62 | 692.86 | 241 | 0.990 | 165,039.38 | 238.20 | 1,717.00 | 408,991.41 |
| 57 | 776.43 | 221 | 1.024 | 175,277.62 | 225.75 | 2,029.00 | 458,043.81 |
| Totals | 2,245.71 | | | 537,494.29 | 260.97 | 4,892.00 | 1,156,347.64 |

Note: The effect of the new cooling tower is a 0.01 kW/ton decrease per degree decrease in approach temperature for the post-retrofit case only.

Site 1909: Results for Heat Exchanger

| | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 483,305 | 80 | | |
| QC | 289,647 | 67 | 380,594 | 88 |
| Realization Rate | 0.60 | 0.83 | | |

| Post-Retrofit Heat Exchanger | |
|---|---|
| Nom. Eff | 0 |
| Nom. Tons | 150 |
| nom kw | 0 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 92 | 0.29 | 115 | 0.000 | 0.00 | 0.00 | 0.29 | 0.00 |
| 87 | 8.00 | 115 | 0.000 | 0.00 | 0.00 | 3.14 | |
| 82 | 16.57 | 115 | 0.000 | 0.00 | 0.00 | 10.86 | |
| 77 | 50.00 | 115 | 0.000 | 0.00 | 0.00 | 28.71 | |
| 72 | 125.43 | 115 | 0.000 | 0.00 | 0.00 | 69.71 | |
| 67 | 280.14 | 115 | 0.000 | 0.00 | 0.00 | 227.43 | 0.00 |
| 62 | 764.14 | 115 | 0.000 | 0.00 | 0.00 | 731.00 | 0.00 |
| 57 | 1,684.57 | 115 | 0.000 | 0.00 | 0.00 | 1,713.43 | 0.00 |
| 52 | 1,506.86 | 115 | 0.000 | 0.00 | 0.00 | 1,769.00 | 0.00 |
| Totals | 4,436.00 | | | 0.00 | 0.00 | 4,553.57 | 0.00 |

| Title 24 Baseline Chiller | |
|---|---|
| Nom. Eff | 0.837 |
| Nom. Tons | 150 |
| nom kw | 126 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 92 | 0.29 | 115 | 0.493 | 16.18 | 56.65 |
| 87 | 8.00 | 115 | 0.503 | 462.79 | 57.85 |
| 82 | 16.57 | 115 | 0.514 | 978.96 | 59.08 |
| 77 | 50.00 | 115 | 0.525 | 3,016.07 | 60.32 |
| 72 | 125.43 | 115 | 0.536 | 7,724.40 | 61.58 |
| 67 | 280.14 | 115 | 0.547 | 17,609.85 | 62.86 |
| 62 | 764.14 | 115 | 0.558 | 49,017.80 | 64.15 |
| 57 | 1,684.57 | 115 | 0.569 | 110,244.08 | 65.44 |
| 52 | 1,506.86 | 115 | 0.580 | 100,576.98 | 66.75 |
| Totals | 4,436.00 | | | 289,647.12 | 66.75 |

| Pre-Retrofit Chiller | |
|---|---|
| Nom. Eff | 1.050 |
| Nom. Tons | 150 |
| nom kw | 158 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 92 | 0.29 | 115 | 0.647 | 21.27 | 74.43 | 0.29 | 21.27 |
| 87 | 8.00 | 115 | 0.661 | 608.10 | 76.01 | 3.14 | 238.90 |
| 82 | 16.57 | 115 | 0.675 | 1,286.35 | 77.62 | 10.86 | 842.78 |
| 77 | 50.00 | 115 | 0.689 | 3,963.10 | 79.26 | 28.71 | 2,275.95 |
| 72 | 125.43 | 115 | 0.704 | 10,149.82 | 80.92 | 69.71 | 5,641.36 |
| 67 | 280.14 | 115 | 0.718 | 23,139.22 | 82.60 | 227.43 | 18,785.13 |
| 62 | 764.14 | 115 | 0.733 | 64,409.05 | 84.29 | 731.00 | 61,615.46 |
| 57 | 1,684.57 | 115 | 0.748 | 144,859.97 | 85.99 | 1,713.43 | 147,341.46 |
| 52 | 1,506.86 | 115 | 0.763 | 132,157.46 | 87.70 | 1,769.00 | 155,148.45 |
| Totals | 4,436.00 | | | 380,594.34 | 87.70 | 4,553.57 | 391,910.75 |

Site 1909: Post-Retrofit Chiller #1

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.61 |
| Nom. Tons | 500 |
| nom kw | 305 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 102 | 400 | 81.3 | 48.0 | 507 | 0.790 | 0.784 | 0.885 | 0.1524 | 6.56 | 0.536 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1909: Post-Retrofit Chiller #2

| Centrifugal Chiller (Water-Source | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.61 |
| Nom. Tons | 500 |
| nom kw | 305 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 97 | 380 | 81.3 | 48.0 | 507 | 0.751 | 0.747 | 0.885 | 0.1527 | 6.55 | 0.537 |
| 92 | 361 | 81.3 | 47.0 | 504 | 0.71 | 0.71 | 0.90 | 0.1557 | 6.42 | 0.547 |
| 87 | 341 | 81.3 | 46.0 | 501 | 0.68 | 0.68 | 0.91 | 0.1589 | 6.29 | 0.559 |
| 82 | 321 | 81.3 | 45.0 | 497 | 0.65 | 0.65 | 0.93 | 0.1623 | 6.16 | 0.571 |
| 77 | 301 | 81.3 | 44.0 | 492 | 0.61 | 0.62 | 0.94 | 0.1660 | 6.02 | 0.584 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1909: Post-Retrofit Chiller #3

| Centrifugal Chiller (Water-Source | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.58 |
| Nom. Tons | 150 |
| nom kw | 87 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 72 | 140 | 81.3 | 50.3 | 153 | 0.92 | 0.91 | 0.85 | 0.1394 | 7.17 | 0.490 |
| 67 | 130 | 81.3 | 48.1 | 152 | 0.86 | 0.85 | 0.88 | 0.1445 | 6.92 | 0.508 |
| 62 | 120 | 81.3 | 45.9 | 150 | 0.80 | 0.80 | 0.92 | 0.1500 | 6.67 | 0.527 |
| 57 | 110 | 81.3 | 43.7 | 147 | 0.75 | 0.75 | 0.95 | 0.1557 | 6.42 | 0.547 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1909: Post-Retrofit Chiller #4

| Centrifugal Chiller (Water-Source | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.58 |
| Nom. Tons | 150 |
| nom kw | 87 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 72 | 140 | 81.3 | 50.2 | 153 | 0.92 | 0.91 | 0.85 | 0.1396 | 7.16 | 0.491 |
| 67 | 130 | 81.3 | 48.7 | 152 | 0.85 | 0.85 | 0.88 | 0.1432 | 6.98 | 0.503 |
| 62 | 120 | 81.3 | 47.1 | 151 | 0.79 | 0.79 | 0.90 | 0.1471 | 6.80 | 0.517 |
| 57 | 110 | 81.3 | 45.5 | 150 | 0.74 | 0.73 | 0.92 | 0.1513 | 6.61 | 0.532 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1909: Post-Retrofit Heat Exchanger

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0 |
| Nom. Tons | 150 |
| nom kw | 0 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 92 | 115 | 75 | 64 | 125 | 0.92 | 0.91 | 0.59 | 0.0000 | #DIV/0! | 0.000 |
| 87 | 115 | 75 | 63 | 129 | 0.89 | 0.88 | 0.61 | 0.0000 | #DIV/0! | 0.000 |
| 82 | 115 | 75 | 62 | 132 | 0.87 | 0.86 | 0.62 | 0.0000 | #DIV/0! | 0.000 |
| 77 | 115 | 75 | 61 | 136 | 0.85 | 0.84 | 0.63 | 0.0000 | #DIV/0! | 0.000 |
| 72 | 115 | 75 | 60 | 139 | 0.83 | 0.82 | 0.64 | 0.0000 | #DIV/0! | 0.000 |
| 67 | 115 | 75 | 59 | 141 | 0.81 | 0.81 | 0.66 | 0.0000 | #DIV/0! | 0.000 |
| 62 | 115 | 75 | 58 | 144 | 0.80 | 0.79 | 0.67 | 0.0000 | #DIV/0! | 0.000 |
| 57 | 115 | 75 | 57 | 146 | 0.79 | 0.78 | 0.68 | 0.0000 | #DIV/0! | 0.000 |
| 52 | 115 | 75 | 56 | 148 | 0.78 | 0.77 | 0.70 | 0.0000 | #DIV/0! | 0.000 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1909: Baseline Chiller #1

| Centrifugal Chiller (Water-Source | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 500 |
| nom kw | 374.043 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 102 | 400 | 81.3 | 48.0 | 507 | 0.790 | 0.784 | 0.885 | 0.1869 | 5.35 | 0.657 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1909: Baseline Chiller #2

| Centrifugal Chiller (Water-Source | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 500 |
| nom kw | 374.043 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 97 | 380 | 81.3 | 48.0 | 507 | 0.751 | 0.747 | 0.885 | 0.1873 | 5.34 | 0.658 |
| 92 | 361 | 81.3 | 47.0 | 504 | 0.71 | 0.71 | 0.90 | 0.1910 | 5.24 | 0.671 |
| 87 | 341 | 81.3 | 46.0 | 501 | 0.68 | 0.68 | 0.91 | 0.1949 | 5.13 | 0.685 |
| 82 | 321 | 81.3 | 45.0 | 497 | 0.65 | 0.65 | 0.93 | 0.1990 | 5.02 | 0.700 |
| 77 | 301 | 81.3 | 44.0 | 492 | 0.61 | 0.62 | 0.94 | 0.2036 | 4.91 | 0.716 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1909: Baseline Chiller #3

| Centrifugal Chiller (Water-Source | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.837 |
| Nom. Tons | 150 |
| nom kw | 125.571 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 72 | 137 | 81.3 | 50.3 | 153 | 0.89 | 0.89 | 0.85 | 0.2010 | 4.97 | 0.707 |
| 67 | 129 | 81.3 | 48.1 | 152 | 0.85 | 0.84 | 0.88 | 0.2086 | 4.79 | 0.733 |
| 62 | 120 | 81.3 | 45.9 | 150 | 0.80 | 0.80 | 0.92 | 0.2164 | 4.62 | 0.761 |
| 57 | 112 | 81.3 | 43.7 | 147 | 0.76 | 0.76 | 0.95 | 0.2246 | 4.45 | 0.790 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1909: Baseline Chiller #4

| Centrifugal Chiller (Water-Source | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.837 |
| Nom. Tons | 150 |
| nom kw | 125.571 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 72 | 149 | 81.3 | 50.2 | 153 | 0.97 | 0.97 | 0.85 | 0.2021 | 4.95 | 0.710 |
| 67 | 128 | 81.3 | 48.7 | 152 | 0.84 | 0.84 | 0.88 | 0.2067 | 4.84 | 0.727 |
| 62 | 108 | 81.3 | 47.1 | 151 | 0.71 | 0.71 | 0.90 | 0.2134 | 4.69 | 0.750 |
| 57 | 87 | 81.3 | 45.5 | 150 | 0.58 | 0.60 | 0.92 | 0.2237 | 4.47 | 0.787 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1909: Baseline Heat Exchanger

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.837 |
| Nom. Tons | 150 |
| nom kw | 126 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 92 | 115 | 75 | 64 | 125 | 0.92 | 0.91 | 0.59 | 0.1401 | 7.14 | 0.493 |
| 87 | 115 | 75 | 63 | 129 | 0.89 | 0.88 | 0.61 | 0.1431 | 6.99 | 0.503 |
| 82 | 115 | 75 | 62 | 132 | 0.87 | 0.86 | 0.62 | 0.1461 | 6.84 | 0.514 |
| 77 | 115 | 75 | 61 | 136 | 0.85 | 0.84 | 0.63 | 0.1492 | 6.70 | 0.525 |
| 72 | 115 | 75 | 60 | 139 | 0.83 | 0.82 | 0.64 | 0.1523 | 6.57 | 0.536 |
| 67 | 115 | 75 | 59 | 141 | 0.81 | 0.81 | 0.66 | 0.1555 | 6.43 | 0.547 |
| 62 | 115 | 75 | 58 | 144 | 0.80 | 0.79 | 0.67 | 0.1586 | 6.30 | 0.558 |
| 57 | 115 | 75 | 57 | 146 | 0.79 | 0.78 | 0.68 | 0.1619 | 6.18 | 0.569 |
| 52 | 115 | 75 | 56 | 148 | 0.78 | 0.77 | 0.70 | 0.1651 | 6.06 | 0.580 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1909: Pre-Retrofit Chiller #1

| Centrifugal Chiller (Water-Sourcea | b | c | d | e | f |
|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 1.050 |
| Nom. Tons | 500 |
| nom kw | 525 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 102 | 400 | 81.3 | 48.0 | 507 | 0.790 | 0.784 | 0.885 | 0.2623 | 3.81 | 0.922 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1909: Pre-Retrofit Chiller #2

| Centrifugal Chiller (Water-Sourcea | | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 1.050 |
| Nom. Tons | 500 |
| nom kw | 525.000 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 97 | 380 | 81.3 | 48.0 | 507 | 0.751 | 0.747 | 0.885 | 0.2629 | 3.80 | 0.924 |
| 92 | 361 | 81.3 | 47.0 | 504 | 0.71 | 0.71 | 0.90 | 0.2680 | 3.73 | 0.942 |
| 87 | 341 | 81.3 | 46.0 | 501 | 0.68 | 0.68 | 0.91 | 0.2735 | 3.66 | 0.962 |
| 82 | 321 | 81.3 | 45.0 | 497 | 0.65 | 0.65 | 0.93 | 0.2794 | 3.58 | 0.982 |
| 77 | 301 | 81.3 | 44.0 | 492 | 0.61 | 0.62 | 0.94 | 0.2857 | 3.50 | 1.005 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1909: Pre-Retrofit Chiller #3

| Centrifugal Chiller (Water-Source | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 1.1 |
| Nom. Tons | 150 |
| nom kw | 165 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 72 | 140 | 81.3 | 50.3 | 153 | 0.92 | 0.91 | 0.85 | 0.2643 | 3.78 | 0.929 |
| 67 | 130 | 81.3 | 48.1 | 152 | 0.86 | 0.85 | 0.88 | 0.2741 | 3.65 | 0.964 |
| 62 | 120 | 81.3 | 45.9 | 150 | 0.80 | 0.80 | 0.92 | 0.2844 | 3.52 | 1.000 |
| 57 | 110 | 81.3 | 43.7 | 147 | 0.75 | 0.75 | 0.95 | 0.2953 | 3.39 | 1.038 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1909: Pre-Retrofit Chiller #4

| Centrifugal Chiller (Water-Source | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 1.1 |
| Nom. Tons | 150 |
| nom kw | 165 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 72 | 140 | 81.3 | 50.2 | 153 | 0.92 | 0.91 | 0.85 | 0.2648 | 3.78 | 0.931 |
| 67 | 130 | 81.3 | 48.7 | 152 | 0.85 | 0.85 | 0.88 | 0.2716 | 3.68 | 0.955 |
| 62 | 120 | 81.3 | 47.1 | 151 | 0.79 | 0.79 | 0.90 | 0.2789 | 3.59 | 0.981 |
| 57 | 110 | 81.3 | 45.5 | 150 | 0.74 | 0.73 | 0.92 | 0.2869 | 3.49 | 1.009 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1909: Pre-Retrofit Heat Exchanger

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 1.10 |
| Nom. Tons | 150 |
| nom kw | 165 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 92 | 115 | 75 | 64 | 125 | 0.92 | 0.91 | 0.59 | 0.1841 | 5.43 | 0.647 |
| 87 | 115 | 75 | 63 | 129 | 0.89 | 0.88 | 0.61 | 0.1880 | 5.32 | 0.661 |
| 82 | 115 | 75 | 62 | 132 | 0.87 | 0.86 | 0.62 | 0.1920 | 5.21 | 0.675 |
| 77 | 115 | 75 | 61 | 136 | 0.85 | 0.84 | 0.63 | 0.1960 | 5.10 | 0.689 |
| 72 | 115 | 75 | 60 | 139 | 0.83 | 0.82 | 0.64 | 0.2001 | 5.00 | 0.704 |
| 67 | 115 | 75 | 59 | 141 | 0.81 | 0.81 | 0.66 | 0.2043 | 4.90 | 0.718 |
| 62 | 115 | 75 | 58 | 144 | 0.80 | 0.79 | 0.67 | 0.2085 | 4.80 | 0.733 |
| 57 | 115 | 75 | 57 | 146 | 0.79 | 0.78 | 0.68 | 0.2127 | 4.70 | 0.748 |
| 52 | 115 | 75 | 56 | 148 | 0.78 | 0.77 | 0.70 | 0.2169 | 4.61 | 0.763 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1909: Weather Data for Chiller #2

TMY temperature data for climate zone 3

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 0 | 0 | 1 | 4 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 37 | 6 | 9 | 13 | 13 | 16 | 15 | 18 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 6 | |
| 42 | 28 | 31 | 34 | 46 | 45 | 44 | 38 | 28 | 12 | 5 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 5 | 6 | 7 | 16 | 21 | 26 | |
| 47 | 72 | 77 | 79 | 84 | 71 | 66 | 70 | 65 | 43 | 31 | 12 | 8 | 6 | 3 | 2 | 2 | 2 | 6 | 21 | 32 | 44 | 43 | 48 | 54 | |
| 52 | 120 | 125 | 125 | 116 | 127 | 122 | 104 | 85 | 79 | 68 | 60 | 43 | 26 | 20 | 17 | 21 | 36 | 53 | 68 | 78 | 93 | 107 | 124 | 127 | |
| 57 | 116 | 105 | 100 | 90 | 95 | 106 | 112 | 120 | 104 | 89 | 83 | 79 | 68 | 70 | 80 | 79 | 95 | 108 | 115 | 129 | 129 | 137 | 127 | 125 | |
| 62 | 21 | 17 | 12 | 11 | 9 | 11 | 19 | 58 | 98 | 102 | 91 | 77 | 77 | 83 | 79 | 84 | 91 | 111 | 109 | 99 | 83 | 55 | 35 | 25 | |
| 67 | 2 | 0 | 1 | 1 | 1 | 1 | 3 | 5 | 20 | 56 | 74 | 77 | 72 | 78 | 84 | 78 | 83 | 60 | 38 | 19 | 9 | 4 | 5 | 2 | |
| 72 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 9 | 32 | 51 | 64 | 61 | 58 | 57 | 37 | 19 | 9 | 2 | 0 | 0 | 0 | 0 | |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 10 | 21 | 31 | 30 | 28 | 28 | 15 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 125 |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 8 | 13 | 11 | 11 | 9 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 41.42857 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 7 | 5 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.714286 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| On Hours | | | | | | | 0 | 0 | 1 | 5 | 12 | 30 | 52 | 49 | 44 | 43 | 20 | 6 | | | | | | | 187.14 |

Note: Total "On Hours" value has been scaled by 5/7 to account for M-F operation only

Actual temperature by hour from 09/01/98 to 08/31/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 37 | 4 | 3 | 3 | 7 | 5 | 7 | 9 | 7 | 5 | 2 | . | . | . | . | . | . | . | . | . | . | . | . | 2 | 2 | |
| 42 | 24 | 23 | 31 | 27 | 34 | 33 | 34 | 30 | 15 | 19 | 19 | 8 | 4 | 3 | 2 | 3 | 3 | 5 | 8 | 13 | 12 | 15 | 20 | 19 | |
| 47 | 114 | 124 | 122 | 131 | 135 | 134 | 123 | 105 | 97 | 60 | 50 | 43 | 30 | 26 | 20 | 16 | 25 | 34 | 42 | 59 | 78 | 81 | 82 | 102 | |
| 52 | 221 | 228 | 226 | 229 | 228 | 214 | 193 | 162 | 147 | 148 | 119 | 114 | 97 | 92 | 81 | 91 | 116 | 152 | 184 | 197 | 212 | 223 | 234 | 233 | |
| 57 | 196 | 188 | 190 | 189 | 176 | 189 | 183 | 194 | 186 | 163 | 158 | 145 | 149 | 142 | 156 | 170 | 189 | 194 | 220 | 224 | 207 | 205 | 197 | 196 | |
| 62 | 56 | 49 | 45 | 32 | 41 | 38 | 70 | 94 | 122 | 149 | 150 | 155 | 151 | 169 | 181 | 173 | 157 | 146 | 117 | 90 | 80 | 78 | 72 | 63 | |
| 67 | 6 | 6 | 4 | 6 | 2 | 6 | 8 | 25 | 43 | 69 | 92 | 99 | 115 | 108 | 99 | 98 | 74 | 53 | 23 | 22 | 29 | 19 | 14 | 6 | |
| 72 | . | . | . | . | . | . | 1 | 4 | 6 | 10 | 27 | 36 | 37 | 34 | 34 | 26 | 25 | 23 | 25 | 16 | 3 | . | . | . | |
| 77 | . | . | . | . | . | . | . | . | . | 1 | 6 | 17 | 23 | 29 | 28 | 28 | 25 | 11 | 2 | . | . | . | . | . | 168 |
| 82 | . | . | . | . | . | . | . | . | . | . | . | 2 | 13 | 13 | 16 | 12 | 7 | 3 | . | . | . | . | . | . | 66 |
| 87 | . | . | . | . | . | . | . | . | . | . | . | 2 | 2 | 4 | 4 | 4 | . | . | . | . | . | . | . | . | 16 |
| 92 | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | 1 |
| 97 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0.00 |
| On Hours | | | | | | | 0 | 0 | 0 | 1 | 6 | 21 | 38 | 47 | 48 | 44 | 32 | 14 | | | | | | | 251.00 |

Actual temperature by hour from 07/15/97 to 06/24/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 37 | 4 | 3 | 3 | 7 | 5 | 7 | 9 | 7 | 5 | 2 | . | . | . | . | . | . | . | . | . | . | . | . | 2 | 2 | |
| 42 | 24 | 23 | 31 | 30 | 39 | 44 | 41 | 33 | 15 | 19 | 19 | 8 | 4 | 3 | 2 | 3 | 3 | 5 | 8 | 13 | 12 | 15 | 20 | 19 | |
| 47 | 160 | 182 | 189 | 200 | 203 | 198 | 184 | 165 | 142 | 86 | 63 | 54 | 36 | 28 | 24 | 18 | 27 | 42 | 53 | 77 | 99 | 106 | 116 | 141 | |
| 52 | 352 | 368 | 355 | 367 | 374 | 365 | 330 | 283 | 262 | 256 | 225 | 207 | 167 | 146 | 130 | 141 | 187 | 231 | 290 | 309 | 329 | 348 | 364 | 364 | |
| 57 | 435 | 400 | 407 | 399 | 389 | 394 | 399 | 391 | 340 | 328 | 294 | 272 | 289 | 283 | 293 | 318 | 345 | 379 | 405 | 422 | 428 | 431 | 431 | 446 | |
| 62 | 166 | 171 | 165 | 150 | 145 | 147 | 156 | 188 | 247 | 277 | 286 | 282 | 264 | 281 | 303 | 308 | 297 | 267 | 251 | 220 | 194 | 201 | 185 | 159 | |
| 67 | 26 | 22 | 21 | 18 | 16 | 16 | 49 | 95 | 128 | 142 | 159 | 188 | 194 | 192 | 193 | 177 | 163 | 159 | 107 | 102 | 101 | 65 | 48 | 37 | |
| 72 | 2 | 2 | . | . | . | . | 3 | 9 | 30 | 56 | 110 | 102 | 131 | 133 | 121 | 117 | 81 | 51 | 44 | 23 | 6 | 2 | 2 | 3 | |
| 77 | 2 | . | . | . | . | . | . | . | 2 | 5 | 11 | 41 | 55 | 66 | 53 | 49 | 40 | 26 | 12 | 5 | 2 | 3 | 3 | . | 348 |
| 82 | . | . | . | . | . | . | . | . | . | . | 4 | 15 | 26 | 25 | 37 | 27 | 23 | 9 | 1 | . | . | . | . | . | 166 |
| 87 | . | . | . | . | . | . | . | . | . | . | . | 2 | 5 | 9 | 10 | 10 | 3 | 2 | . | . | . | . | . | . | 41 |
| 92 | . | . | . | . | . | . | . | . | . | . | . | . | . | 5 | 5 | 3 | 2 | . | . | . | . | . | . | . | 15 |
| 97 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0.00 |
| On Hours | | | | | | | 0 | 0 | 2 | 5 | 15 | 58 | 86 | 105 | 105 | 89 | 68 | 37 | | | | | | | 570.00 |

Site 1909: Weather Data for Chillers #3&4

TMY temperature data for climate zone 3

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 0 | 0 | 1 | 4 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 37 | 6 | 9 | 13 | 13 | 16 | 15 | 18 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 6 | |
| 42 | 28 | 31 | 34 | 46 | 45 | 44 | 38 | 28 | 12 | 5 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 5 | 6 | 7 | 16 | 21 | 26 | |
| 47 | 72 | 77 | 79 | 84 | 71 | 66 | 70 | 65 | 43 | 31 | 12 | 8 | 6 | 3 | 2 | 2 | 2 | 6 | 21 | 32 | 44 | 43 | 48 | 54 | |
| 52 | 120 | 125 | 125 | 116 | 127 | 122 | 104 | 85 | 79 | 68 | 60 | 43 | 26 | 20 | 17 | 21 | 36 | 53 | 68 | 78 | 93 | 107 | 124 | 127 | |
| 57 | 116 | 105 | 100 | 90 | 95 | 106 | 112 | 120 | 104 | 89 | 83 | 79 | 68 | 70 | 80 | 79 | 95 | 108 | 115 | 129 | 129 | 137 | 127 | 125 | 776.4286 |
| 62 | 21 | 17 | 12 | 11 | 9 | 11 | 19 | 58 | 98 | 102 | 91 | 77 | 77 | 83 | 79 | 84 | 91 | 111 | 109 | 99 | 83 | 55 | 35 | 25 | 692.8571 |
| 67 | 2 | 0 | 1 | 1 | 1 | 1 | 3 | 5 | 20 | 56 | 74 | 77 | 72 | 78 | 84 | 78 | 83 | 60 | 38 | 19 | 9 | 4 | 5 | 2 | 492.8571 |
| 72 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 9 | 32 | 51 | 64 | 61 | 58 | 57 | 37 | 19 | 9 | 2 | 0 | 0 | 0 | 0 | 283.5714 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 10 | 21 | 31 | 30 | 28 | 28 | 15 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 8 | 13 | 11 | 11 | 9 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 7 | 5 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| On Hours | | | | | | | 134 | 185 | 229 | 256 | 280 | 284 | 281 | 292 | 301 | 298 | 306 | 298 | | | | | | | 2245.71 |

Note: Total "On Hours" value has been scaled by 5/7 to account for M-F operation only

Actual temperature by hour from 09/01/98 to 08/31/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 37 | 4 | 3 | 3 | 7 | 5 | 7 | 9 | 7 | 5 | 2 | . | . | . | . | . | . | . | . | . | . | . | . | 2 | 2 | |
| 42 | 24 | 23 | 31 | 27 | 34 | 33 | 34 | 30 | 15 | 19 | 19 | 8 | 4 | 3 | 2 | 3 | 3 | 5 | 8 | 13 | 12 | 15 | 20 | 19 | |
| 47 | 114 | 124 | 122 | 131 | 135 | 134 | 123 | 105 | 97 | 60 | 50 | 43 | 30 | 26 | 20 | 16 | 25 | 34 | 42 | 59 | 78 | 81 | 82 | 102 | |
| 52 | 221 | 228 | 226 | 229 | 228 | 214 | 193 | 162 | 147 | 148 | 119 | 114 | 97 | 92 | 81 | 91 | 116 | 152 | 184 | 197 | 212 | 223 | 234 | 233 | |
| 57 | 196 | 188 | 190 | 189 | 176 | 189 | 183 | 194 | 186 | 163 | 158 | 145 | 149 | 142 | 156 | 170 | 189 | 194 | 220 | 224 | 207 | 205 | 197 | 196 | 2029 |
| 62 | 56 | 49 | 45 | 32 | 41 | 38 | 70 | 94 | 122 | 149 | 150 | 155 | 151 | 169 | 181 | 173 | 157 | 146 | 117 | 90 | 80 | 78 | 72 | 63 | 1717 |
| 67 | 6 | 6 | 4 | 6 | 2 | 6 | 8 | 25 | 43 | 69 | 92 | 99 | 115 | 108 | 99 | 98 | 74 | 53 | 23 | 22 | 29 | 19 | 14 | 6 | 883 |
| 72 | . | . | . | . | . | . | 1 | 4 | 6 | 10 | 27 | 36 | 37 | 34 | 34 | 26 | 25 | 23 | 25 | 16 | 3 | . | . | . | 263 |
| 77 | . | . | . | . | . | . | . | . | . | 1 | 6 | 17 | 23 | 29 | 28 | 28 | 25 | 11 | 2 | . | . | . | . | . | |
| 82 | . | . | . | . | . | . | . | . | . | . | . | 2 | 13 | 13 | 16 | 12 | 7 | 3 | . | . | . | . | . | . | |
| 87 | . | . | . | . | . | . | . | . | . | . | . | 2 | 2 | 4 | 4 | 4 | . | . | . | . | . | . | . | . | |
| 92 | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | |
| 97 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| On Hours | | | | | | | 262 | 317 | 357 | 391 | 427 | 435 | 452 | 453 | 470 | 467 | 445 | 416 | | | | | | | 4892.00 |

Actual temperature by hour from 07/15/97 to 06/24/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 37 | 4 | 3 | 3 | 7 | 5 | 7 | 9 | 7 | 5 | 2 | . | . | . | . | . | . | . | . | . | . | . | . | 2 | 2 | |
| 42 | 24 | 23 | 31 | 30 | 39 | 44 | 41 | 33 | 15 | 19 | 19 | 8 | 4 | 3 | 2 | 3 | 3 | 5 | 8 | 13 | 12 | 15 | 20 | 19 | |
| 47 | 160 | 182 | 189 | 200 | 203 | 198 | 184 | 165 | 142 | 86 | 63 | 54 | 36 | 28 | 24 | 18 | 27 | 42 | 53 | 77 | 99 | 106 | 116 | 141 | |
| 52 | 352 | 368 | 355 | 367 | 374 | 365 | 330 | 283 | 262 | 256 | 225 | 207 | 167 | 146 | 130 | 141 | 187 | 231 | 290 | 309 | 329 | 348 | 364 | 364 | |
| 57 | 435 | 400 | 407 | 399 | 389 | 394 | 399 | 391 | 340 | 328 | 294 | 272 | 289 | 283 | 293 | 318 | 345 | 379 | 405 | 422 | 428 | 431 | 431 | 446 | 3931 |
| 62 | 166 | 171 | 165 | 150 | 145 | 147 | 156 | 188 | 247 | 277 | 286 | 282 | 264 | 281 | 303 | 308 | 297 | 267 | 251 | 220 | 194 | 201 | 185 | 159 | 3156 |
| 67 | 26 | 22 | 21 | 18 | 16 | 16 | 49 | 95 | 128 | 142 | 159 | 188 | 194 | 192 | 193 | 177 | 163 | 159 | 107 | 102 | 101 | 65 | 48 | 37 | 1839 |
| 72 | 2 | 2 | . | . | . | . | 3 | 9 | 30 | 56 | 110 | 102 | 131 | 133 | 121 | 117 | 81 | 51 | 44 | 23 | 6 | 2 | 2 | 3 | 944 |
| 77 | 2 | . | . | . | . | . | . | . | 2 | 5 | 11 | 41 | 55 | 66 | 53 | 49 | 40 | 26 | 12 | 5 | 2 | 3 | 3 | . | |
| 82 | . | . | . | . | . | . | . | . | . | . | 4 | 15 | 26 | 25 | 37 | 27 | 23 | 9 | 1 | . | . | . | . | . | |
| 87 | . | . | . | . | . | . | . | . | . | . | . | 2 | 5 | 9 | 10 | 10 | 3 | 2 | . | . | . | . | . | . | |
| 92 | . | . | . | . | . | . | . | . | . | . | . | . | . | 5 | 5 | 3 | 2 | . | . | . | . | . | . | . | |
| 97 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| On Hours | | | | | | | 607 | 683 | 745 | 803 | 849 | 844 | 878 | 889 | 910 | 920 | 886 | 856 | | | | | | | 9870.00 |

Site 1909: Weather Data for Heat Exchanger

TMY temperature data for climate zone 3

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 0 | 0 | 1 | 4 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 37 | 6 | 9 | 13 | 13 | 16 | 15 | 18 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 6 | |
| 42 | 28 | 31 | 34 | 46 | 45 | 44 | 38 | 28 | 12 | 5 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 5 | 6 | 7 | 16 | 21 | 26 | |
| 47 | 72 | 77 | 79 | 84 | 71 | 66 | 70 | 65 | 43 | 31 | 12 | 8 | 6 | 3 | 2 | 2 | 2 | 6 | 21 | 32 | 44 | 43 | 48 | 54 | |
| 52 | 120 | 125 | 125 | 116 | 127 | 122 | 104 | 85 | 79 | 68 | 60 | 43 | 26 | 20 | 17 | 21 | 36 | 53 | 68 | 78 | 93 | 107 | 124 | 127 | 1507 |
| 57 | 116 | 105 | 100 | 90 | 95 | 106 | 112 | 120 | 104 | 89 | 83 | 79 | 68 | 70 | 80 | 79 | 95 | 108 | 115 | 129 | 129 | 137 | 127 | 125 | 1685 |
| 62 | 21 | 17 | 12 | 11 | 9 | 11 | 19 | 58 | 98 | 102 | 91 | 77 | 77 | 83 | 79 | 84 | 91 | 111 | 109 | 99 | 83 | 55 | 35 | 25 | 764 |
| 67 | 2 | 0 | 1 | 1 | 1 | 1 | 3 | 5 | 20 | 56 | 74 | 77 | 72 | 78 | 84 | 78 | 83 | 60 | 38 | 19 | 9 | 4 | 5 | 2 | 280 |
| 72 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 9 | 32 | 51 | 64 | 61 | 58 | 57 | 37 | 19 | 9 | 2 | 0 | 0 | 0 | 0 | 125 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 10 | 21 | 31 | 30 | 28 | 28 | 15 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 50 |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 8 | 13 | 11 | 11 | 9 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 7 | 5 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| On Hours | 259 | 248 | 238 | 218 | 232 | 240 | 238 | 270 | 309 | 329 | 352 | 357 | 359 | 361 | 362 | 362 | 362 | 357 | 339 | 327 | 314 | 303 | 291 | 279 | 4436 |

Actual temperature by hour from 09/01/98 to 08/31/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 37 | 2 | 1 | 1 | 3 | 2 | 3 | 4 | 3 | 2 | 1 | | | | | | | | | | | | | 1 | 1 | |
| 42 | 13 | 13 | 17 | 15 | 19 | 19 | 20 | 18 | 9 | 11 | 10 | 4 | 2 | 2 | 1 | 2 | 2 | 3 | 5 | 7 | 7 | 9 | 11 | 11 | |
| 47 | 67 | 73 | 73 | 78 | 80 | 79 | 72 | 62 | 54 | 33 | 29 | 24 | 16 | 14 | 11 | 9 | 15 | 21 | 25 | 35 | 46 | 47 | 49 | 59 | |
| 52 | 129 | 132 | 130 | 133 | 133 | 124 | 113 | 93 | 88 | 88 | 69 | 68 | 59 | 55 | 48 | 54 | 67 | 87 | 105 | 112 | 121 | 129 | 133 | 134 | 1769 |
| 57 | 112 | 108 | 110 | 107 | 100 | 109 | 105 | 113 | 107 | 93 | 92 | 85 | 85 | 81 | 91 | 97 | 107 | 111 | 127 | 132 | 123 | 120 | 117 | 115 | 1713 |
| 62 | 34 | 30 | 27 | 21 | 25 | 23 | 41 | 54 | 72 | 88 | 88 | 87 | 86 | 98 | 104 | 99 | 92 | 85 | 69 | 52 | 45 | 44 | 41 | 36 | 731 |
| 67 | 3 | 3 | 2 | 3 | 1 | 3 | 5 | 15 | 25 | 39 | 53 | 59 | 68 | 62 | 57 | 58 | 44 | 31 | 13 | 13 | 16 | 11 | 8 | 4 | 227 |
| 72 | | | | | | | | 2 | 3 | 7 | 16 | 21 | 21 | 20 | 20 | 16 | 14 | 13 | 15 | 9 | 2 | | | | 70 |
| 77 | | | | | | | | | | | 3 | 10 | 14 | 17 | 17 | 15 | 14 | 7 | 1 | | | | | | 29 |
| 82 | | | | | | | | | | | | 1 | 8 | 7 | 8 | 7 | 5 | 2 | | | | | | | 11 |
| 87 | | | | | | | | | | | | 1 | 1 | 3 | 3 | 3 | | | | | | | | | 3 |
| 92 | | | | | | | | | | | | | | 1 | | | | | | | | | | | 0 |
| 97 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| On Hours | 278 | 273 | 269 | 264 | 259 | 259 | 264 | 277 | 295 | 315 | 321 | 332 | 342 | 344 | 348 | 349 | 343 | 336 | 330 | 318 | 307 | 304 | 299 | 289 | 4554 |

Actual temperature by hour from 07/15/97 to 06/24/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 37 | 2 | 1 | 1 | 3 | 2 | 3 | 4 | 3 | 2 | 1 | | | | | | | | | | | | | 1 | 1 | |
| 42 | 13 | 13 | 17 | 17 | 22 | 25 | 24 | 20 | 9 | 11 | 10 | 4 | 2 | 2 | 1 | 2 | 2 | 3 | 5 | 7 | 7 | 9 | 11 | 11 | |
| 47 | 93 | 104 | 111 | 117 | 119 | 117 | 107 | 95 | 80 | 48 | 36 | 30 | 19 | 15 | 13 | 10 | 16 | 26 | 31 | 45 | 58 | 61 | 69 | 80 | |
| 52 | 203 | 212 | 203 | 210 | 214 | 207 | 190 | 161 | 153 | 148 | 127 | 119 | 99 | 85 | 75 | 83 | 106 | 131 | 167 | 178 | 189 | 202 | 207 | 210 | 2824 |
| 57 | 252 | 234 | 237 | 230 | 225 | 230 | 231 | 228 | 194 | 188 | 171 | 159 | 163 | 160 | 169 | 179 | 197 | 215 | 231 | 242 | 245 | 248 | 251 | 260 | 3529 |
| 62 | 97 | 100 | 96 | 90 | 86 | 86 | 91 | 110 | 146 | 163 | 169 | 160 | 151 | 163 | 174 | 178 | 173 | 158 | 149 | 131 | 116 | 116 | 106 | 91 | 1789 |
| 67 | 15 | 12 | 12 | 10 | 9 | 9 | 29 | 55 | 75 | 84 | 90 | 111 | 117 | 112 | 114 | 106 | 98 | 94 | 62 | 58 | 57 | 38 | 29 | 22 | 643 |
| 72 | 1 | 1 | | | | | 1 | 5 | 17 | 32 | 66 | 62 | 76 | 80 | 72 | 69 | 46 | 28 | 25 | 13 | 4 | 1 | 1 | 2 | 206 |
| 77 | 1 | | | | | | | | 1 | 2 | 6 | 23 | 32 | 37 | 30 | 27 | 23 | 16 | 6 | 3 | 1 | 2 | 2 | | 71 |
| 82 | | | | | | | | | | | 2 | 8 | 15 | 14 | 20 | 16 | 13 | 5 | 1 | | | | | | 28 |
| 87 | | | | | | | | | | | | 1 | 3 | 6 | 6 | 5 | 2 | 1 | | | | | | | 7 |
| 92 | | | | | | | | | | | | | | 3 | 3 | 2 | 1 | | | | | | | | 3 |
| 97 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| On Hours | 569 | 559 | 548 | 540 | 534 | 532 | 542 | 559 | 586 | 617 | 631 | 643 | 656 | 660 | 663 | 665 | 659 | 648 | 641 | 625 | 612 | 607 | 596 | 585 | 9099 |

Chiller Replacement (Site 1910)

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | High Efficiency Water-Cooled Chiller |
| Site Description | Office |

**Measure Description**

Replace two of three existing chillers with two high-efficiency water-cooled chillers, one with a VSD.

**Summary of Ex Ante Impact Calculations**

Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and chiller characteristics.

**Comments on PG&E Calculations**

The correct climate zone, chiller size category and building characteristics were used in the application calculations. However, the calibration to customer billing records appears to have over-estimated the chiller contribution to those bills, resulting in an over-estimation of energy impact.

**Evaluation Process**

The evaluation process consists of a review of the application form and supporting documentation, conducting an on-site survey and then computing impacts using the on-site data.

The on-site survey was conducted on July 1, 1999 in Oakland (Climate Zone 3). Information on the retrofit equipment and operating conditions were collected through an inspection of the chiller and through an interview with the Chief Engineer.

Discussions provided data for development of a relationship between chiller loading and outdoor dry bulb. The chiller is available from 6:00 am to 7:00 pm on weekdays only. During the Summer, the 650-ton chiller is brought on line at approximately 50 degrees outside air temperature. The Chief Engineer estimated that the 650-ton chiller reaches 100% loading at approximately 85 degrees outside air temperature. The 450-ton chiller is started when the 650-ton chiller is fully loaded. The 450-ton chiller becomes fully loaded at approximately 100 degrees F. There is also a 200-ton chiller that is used for weekend operation and only on extremely hot days during the week.

Models are calibrated with actual weather, the chiller lock-out temperature, chiller loading under extreme outdoor temperature conditions, chilled water temperature, and condenser water temperature. Energy impacts are based on typical weather data. A Title 24 baseline, nominal efficiency, and typical year bin weather data for the applicable climate zone are used in the bin analysis. To compute the impacts, the following assumptions were used:

- A linear loading strategy was used for the analysis of both the baseline and rebated chillers, which assumed initial loading for the 650-ton chiller at 50 degrees F and 100% loading at 85 Degrees F. From 85 to 100 degrees F, the 650-ton chiller is assumed to be fully loaded. The 450-ton chiller was assumed to have a linear loading strategy with initial loading at 85 degrees F and 100% loading at 100 degrees F.

- Based on a water-cooled chiller greater than 300 tons, a baseline Title 24 efficiency of 0.748 KW/ton was used.

Chiller efficiencies at various temperatures were calculated from updated default performance coefficients provided in a memo to the California Energy Commission titled "1995 Proposed Changes to the ACM Manual Central Plant Cooling Equipment" by Mark Hydeman. These coefficients were used to develop a chiller efficiency curve for the Rebate case and a Title 24 base case. Evaluation-based energy impacts were lower than ex ante estimates, and demand impacts were negligibly lower than ex ante estimates. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 171.00 | 412,260.53 | 0 |
| **Adjusted Engineering** | 169.16 | 255,355.53 | 0 |
| **Engineering Realization Rate** | 0.99 | 0.62 | N/A |

Site 1910: Results Summary

| Overall | Energy | Demand |
|---|---|---|
| MDSS | 412,261 | 171 |
| QC | 255,356 | 169 |
| Chiller #1 | 617 | 46 |
| Chiller #2 | 254,738 | 123 |
| Realization Rate | 0.62 | 0.99 |

Site 1910: Results for Chiller #1

| | Impacts | |
|---|---|---|
| | Energy | Demand |
| MDSS | 412,261 | 171 |
| QC | 617 | 46 |
| Realization Rate | 0.00 | 0.27 |

| Title 24 Baseline Chiller #1 | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 450 |
| nom kw | 336.638 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 102 | 0.00 | 450 | 0.649 | 0.00 | 0.00 |
| 97 | 0.00 | 338 | 0.650 | 0.00 | 0.00 |
| 92 | 0.71 | 225 | 0.688 | 110.65 | 154.91 |
| 87 | 20.00 | 113 | 0.878 | 1,974.91 | 98.75 |
| Totals | 20.71 | | | 2,085.56 | 154.91 |

| Post-Retrofit Chiller #1 | |
|---|---|
| Nom. Eff | 0.526666667 |
| Nom. Tons | 450 |
| nom kw | 237 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 102 | 0.00 | 450 | 0.457 | 0.00 | 0.00 | 0 | 0.00 |
| 97 | 0.00 | 338 | 0.458 | 0.00 | 0.00 | 0 | 0.00 |
| 92 | 0.71 | 225 | 0.485 | 77.90 | 109.06 | 9 | 981.51 |
| 87 | 20.00 | 113 | 0.618 | 1,390.38 | 69.52 | 31 | 2,155.09 |
| Totals | 20.71 | | | 1,468.28 | 109.06 | 40.00 | 3,136.60 |

Site 1910: Results for Chiller #2

| | Impacts | |
|---|---|---|
| | Energy | Demand |
| MDSS | 412,261 | 171 |
| QC | 254,738 | 123 |
| Realization Rate | 0.62 | 0.72 |

| Title 24 Baseline Chiller #2 | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 650 |
| nom kw | 486 |

| Post-Retrofit Chiller #2 | |
|---|---|
| Nom. Eff | 0.52 |
| Nom. Tons | 650 |
| nom kw | 338 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 102 | 0.00 | 650 | 0.649 | 0.00 | 421.76 |
| 97 | 0.00 | 650 | 0.650 | 0.00 | 422.45 |
| 92 | 0.71 | 650 | 0.651 | 302.22 | 423.11 |
| 87 | 20.00 | 650 | 0.652 | 8,474.99 | 423.75 |
| 82 | 41.43 | 569 | 0.619 | 14,591.16 | 352.20 |
| 77 | 125.00 | 488 | 0.609 | 37,121.98 | 296.98 |
| 72 | 290.00 | 406 | 0.607 | 71,549.45 | 246.72 |
| 67 | 520.00 | 325 | 0.619 | 104,583.07 | 201.12 |
| 62 | 770.71 | 244 | 0.656 | 123,234.37 | 159.90 |
| 57 | 858.57 | 163 | 0.756 | 105,439.92 | 122.81 |
| 52 | 485.71 | 81 | 1.103 | 43,546.33 | 89.65 |
| Totals | 3,112.14 | | | 508,843.49 | 423.75 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 102 | 0.00 | 650 | 0.460 | 0.00 | 299.03 | 0 | 0.00 |
| 97 | 0.00 | 650 | 0.461 | 0.00 | 299.52 | 0 | 0.00 |
| 92 | 0.71 | 650 | 0.462 | 214.28 | 299.99 | 9 | 2,699.90 |
| 87 | 20.00 | 650 | 0.462 | 6,008.86 | 300.44 | 31 | 9,313.73 |
| 82 | 41.43 | 569 | 0.387 | 9,128.19 | 220.34 | 62 | 13,660.81 |
| 77 | 125.00 | 488 | 0.318 | 19,352.84 | 154.82 | 98 | 15,172.63 |
| 72 | 290.00 | 406 | 0.306 | 36,057.59 | 124.34 | 206 | 25,613.32 |
| 67 | 520.00 | 325 | 0.301 | 50,887.58 | 97.86 | 441 | 43,156.58 |
| 62 | 770.71 | 244 | 0.319 | 59,962.84 | 77.80 | 744 | 57,884.43 |
| 57 | 858.57 | 163 | 0.368 | 51,304.50 | 59.76 | 835 | 49,895.97 |
| 52 | 485.71 | 81 | 0.537 | 21,188.58 | 43.62 | 555 | 24,211.07 |
| Totals | 3,112.14 | | | 254,105.25 | 300.44 | 2,981.00 | 241,608.43 |

Site 1910: Inputs to Model

| Parameter | Value Reported | Units of Parameter | Notes |
|---|---|---|---|
| City | Oakland | | |
| Climate Zone | 3 | | |
| | | | |
| Chiller #1 Pre-Retrofit Nominal Capacity | 650 | Tons | Application |
| Chiller #1 Post-Retrofit Nominal Capacity | 450 | Tons | Application |
| Chiller #1 Post-Retrofit Nominal Efficiency | 0.527 | kW/ton | Application |
| Chiller #1 Baseline Efficiency | 0.748 | kW/ton | Title 24 Nominal Efficiency for Chiller > 300 Tons |
| | | | |
| Chiller #2 Pre-Retrofit Nominal Capacity | 650 | Tons | Application |
| Chiller #2 Post-Retrofit Nominal Capacity | 650 | Tons | Application |
| Chiller #2 Post-Retrofit Nominal Efficiency | 0.520 | kW/ton | Application |
| Chiller #2 Baseline Efficiency | 0.748 | kW/ton | Title 24 Nominal Efficiency for Chiller > 300 Tons |
| | | | |
| Chiller AM Lockout | 6:00 | AM | Contact provided schedule; M-F |
| Chiller PM Lockout | 19:00 | PM | Contact provided schedule; M-F |
| Chiller Startup OSA Temperature | 50 | F | Contact provided estimate |
| Chiller #1 Max Load OSA Temperature | 100 | F | |
| Chiller #2 Max Load OSA Temperature | 85 | F | |
| Date of Chiller Installation | 5/1/98 | | Contact provided estimate |

Site 1910: Post-Retrofit Chiller #1

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.527 |
| Nom. Tons | 450 |
| nom kw | 237 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 102 | 450 | 78 | 46.0 | 459 | 0.980 | 0.976 | 0.871 | 0.1299 | 7.70 | 0.457 |
| 97 | 338 | 77 | 45.0 | 458 | 0.736 | 0.733 | 0.872 | 0.1301 | 7.68 | 0.458 |
| 92 | 225 | 76 | 44.0 | 457 | 0.492 | 0.518 | 0.874 | 0.1379 | 7.25 | 0.485 |
| 87 | 113 | 75 | 43.0 | 456 | 0.247 | 0.331 | 0.875 | 0.1758 | 5.69 | 0.618 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1910: Post-Retrofit Chiller #2

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.52 |
| Nom. Tons | 650 |
| nom kw | 338 |

| | Current Data | | | Calculated Values | | | | Efficiency | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton | kW/Ton w/ VFD |
| 102 | 650 | 78 | 46.0 | 663 | 0.980 | 0.976 | 0.871 | 0.1283 | 7.80 | 0.451 | 0.460047 |
| 97 | 650 | 77 | 45.0 | 662 | 0.982 | 0.978 | 0.872 | 0.1285 | 7.78 | 0.452 | 0.460798 |
| 92 | 650 | 76 | 44.0 | 660 | 0.984 | 0.980 | 0.874 | 0.1287 | 7.77 | 0.452 | 0.461521 |
| 87 | 650 | 75 | 43.0 | 658 | 0.988 | 0.984 | 0.875 | 0.1289 | 7.76 | 0.453 | 0.46222 |
| 82 | 569 | 74 | 45.0 | 669 | 0.85 | 0.84 | 0.83 | 0.1224 | 8.17 | 0.430 | 0.387403 |
| 77 | 488 | 72 | 44.5 | 670 | 0.73 | 0.73 | 0.82 | 0.1204 | 8.30 | 0.423 | 0.317585 |
| 72 | 406 | 70 | 44.0 | 670 | 0.61 | 0.62 | 0.80 | 0.1201 | 8.33 | 0.422 | 0.306059 |
| 67 | 325 | 68 | 43.5 | 669 | 0.49 | 0.51 | 0.78 | 0.1223 | 8.17 | 0.430 | 0.30111 |
| 62 | 244 | 66 | 43.0 | 667 | 0.37 | 0.42 | 0.77 | 0.1297 | 7.71 | 0.456 | 0.319186 |
| 57 | 163 | 64 | 42.5 | 663 | 0.24 | 0.33 | 0.75 | 0.1494 | 6.69 | 0.525 | 0.367727 |
| 52 | 81 | 62 | 42.0 | 659 | 0.12 | 0.25 | 0.73 | 0.2181 | 4.58 | 0.767 | 0.536905 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1910: Baseline Chiller #1

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 450 |
| nom kw | 336.638 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 102 | 450 | 78 | 46.0 | 459 | 0.980 | 0.976 | 0.871 | 0.1845 | 5.42 | 0.649 |
| 97 | 338 | 77 | 45.0 | 458 | 0.736 | 0.733 | 0.872 | 0.1848 | 5.41 | 0.650 |
| 92 | 225 | 76 | 44.0 | 457 | 0.492 | 0.518 | 0.874 | 0.1958 | 5.11 | 0.688 |
| 87 | 113 | 75 | 43.0 | 456 | 0.247 | 0.331 | 0.875 | 0.2496 | 4.01 | 0.878 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1910: Baseline Chiller #2

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 650 |
| nom kw | 486.255 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 102 | 650 | 78 | 46.0 | 663 | 0.980 | 0.976 | 0.871 | 0.1845 | 5.42 | 0.649 |
| 97 | 650 | 77 | 45.0 | 662 | 0.982 | 0.978 | 0.872 | 0.1848 | 5.41 | 0.650 |
| 92 | 650 | 76 | 44.0 | 660 | 0.984 | 0.980 | 0.874 | 0.1851 | 5.40 | 0.651 |
| 87 | 650 | 75 | 43.0 | 658 | 0.988 | 0.984 | 0.875 | 0.1854 | 5.39 | 0.652 |
| 82 | 569 | 74 | 45.0 | 669 | 0.85 | 0.84 | 0.83 | 0.1761 | 5.68 | 0.619 |
| 77 | 488 | 72 | 44.5 | 670 | 0.73 | 0.73 | 0.82 | 0.1733 | 5.77 | 0.609 |
| 72 | 406 | 70 | 44.0 | 670 | 0.61 | 0.62 | 0.80 | 0.1727 | 5.79 | 0.607 |
| 67 | 325 | 68 | 43.5 | 669 | 0.49 | 0.51 | 0.78 | 0.1760 | 5.68 | 0.619 |
| 62 | 244 | 66 | 43.0 | 667 | 0.37 | 0.42 | 0.77 | 0.1866 | 5.36 | 0.656 |
| 57 | 163 | 64 | 42.5 | 663 | 0.24 | 0.33 | 0.75 | 0.2149 | 4.65 | 0.756 |
| 52 | 81 | 62 | 42.0 | 659 | 0.12 | 0.25 | 0.73 | 0.3138 | 3.19 | 1.103 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1910: Weather Data

TMY temperature data for climate zone 3

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 0 | 0 | 1 | 4 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 37 | 6 | 9 | 13 | 13 | 16 | 15 | 18 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 6 | |
| 42 | 28 | 31 | 34 | 46 | 45 | 44 | 38 | 28 | 12 | 5 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 5 | 6 | 7 | 16 | 21 | 26 | |
| 47 | 72 | 77 | 79 | 84 | 71 | 66 | 70 | 65 | 43 | 31 | 12 | 8 | 6 | 3 | 2 | 2 | 2 | 6 | 21 | 32 | 44 | 43 | 48 | 54 | |
| 52 | 120 | 125 | 125 | 116 | 127 | 122 | 104 | 85 | 79 | 68 | 60 | 43 | 26 | 20 | 17 | 21 | 36 | 53 | 68 | 78 | 93 | 107 | 124 | 127 | 485.71 |
| 57 | 116 | 105 | 100 | 90 | 95 | 106 | 112 | 120 | 104 | 89 | 83 | 79 | 68 | 70 | 80 | 79 | 95 | 108 | 115 | 129 | 129 | 137 | 127 | 125 | 858.57 |
| 62 | 21 | 17 | 12 | 11 | 9 | 11 | 19 | 58 | 98 | 102 | 91 | 77 | 77 | 83 | 79 | 84 | 91 | 111 | 109 | 99 | 83 | 55 | 35 | 25 | 770.71 |
| 67 | 2 | 0 | 1 | 1 | 1 | 1 | 3 | 5 | 20 | 56 | 74 | 77 | 72 | 78 | 84 | 78 | 83 | 60 | 38 | 19 | 9 | 4 | 5 | 2 | 520.00 |
| 72 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 9 | 32 | 51 | 64 | 61 | 58 | 57 | 37 | 19 | 9 | 2 | 0 | 0 | 0 | 0 | 290.00 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 10 | 21 | 31 | 30 | 28 | 28 | 15 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 125.00 |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 8 | 13 | 11 | 11 | 9 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 41.43 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 7 | 5 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20.00 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.71 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| 102 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| On Hours | | | | | | | 238 | 270 | 309 | 329 | 352 | 357 | 359 | 361 | 362 | 362 | 362 | 357 | 339 | | | | | | 3112.14 |

Note: Total "On Hours" value has been scaled by 5/7 to account for M-F operation only

Actual temperature by hour from 11/01/98 to 10/31/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | . | | 1 | 1 | 2 | 2 | 2 | 2 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 3 | |
| 37 | 6 | 8 | 7 | 8 | 10 | 9 | 13 | 10 | 3 | . | . | . | . | . | . | . | . | . | 1 | 2 | 3 | 3 | 2 | 1 | |
| 42 | 21 | 24 | 29 | 32 | 33 | 33 | 28 | 17 | 8 | 8 | 4 | 1 | 1 | . | . | . | 1 | 3 | 3 | 4 | 6 | 10 | 16 | 19 | |
| 47 | 45 | 44 | 44 | 43 | 44 | 43 | 39 | 42 | 38 | 24 | 16 | 12 | 9 | 10 | 7 | 6 | 8 | 13 | 18 | 28 | 37 | 37 | 39 | 44 | |
| 52 | 74 | 73 | 70 | 70 | 71 | 68 | 57 | 55 | 54 | 50 | 43 | 37 | 25 | 23 | 24 | 30 | 39 | 52 | 66 | 70 | 73 | 79 | 76 | 75 | 555 |
| 57 | 79 | 81 | 84 | 80 | 77 | 79 | 83 | 73 | 63 | 58 | 57 | 54 | 55 | 57 | 62 | 61 | 65 | 72 | 75 | 84 | 78 | 79 | 82 | 76 | 835 |
| 62 | 26 | 22 | 18 | 19 | 16 | 20 | 28 | 39 | 59 | 63 | 64 | 61 | 63 | 54 | 57 | 62 | 62 | 67 | 65 | 44 | 42 | 37 | 33 | 34 | 744 |
| 67 | 5 | 4 | 3 | 3 | 3 | 2 | 4 | 11 | 16 | 30 | 41 | 45 | 50 | 55 | 53 | 53 | 48 | 23 | 12 | 16 | 12 | 9 | 6 | 3 | 441 |
| 72 | . | . | . | . | . | . | 2 | 6 | 9 | 14 | 17 | 27 | 27 | 27 | 24 | 19 | 10 | 13 | 11 | 7 | 5 | 2 | 1 | 1 | 206 |
| 77 | . | . | . | . | . | . | . | 1 | 6 | 6 | 7 | 9 | 13 | 12 | 10 | 9 | 13 | 8 | 4 | 1 | . | . | . | . | 98 |
| 82 | . | . | . | . | . | . | . | . | . | 3 | 5 | 6 | 6 | 9 | 11 | 10 | 6 | 5 | 1 | . | . | . | . | . | 62 |
| 87 | . | . | . | . | . | . | . | . | . | . | 2 | 4 | 5 | 6 | 6 | 5 | 3 | . | . | . | . | . | . | . | 31 |
| 92 | . | . | . | . | . | . | . | . | . | . | . | . | 2 | 3 | 2 | 1 | 1 | . | . | . | . | . | . | . | 9 |
| 97 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| 102 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| On Hours | | | | | | | 174 | 185 | 207 | 224 | 236 | 243 | 246 | 246 | 249 | 250 | 247 | 240 | 234 | | | | | | 2981.00 |

Actual temperature by hour from 05/01/98 to 10/31/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | . | . | 1 | 1 | 2 | 2 | 2 | 2 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 3 | |
| 37 | 6 | 8 | 7 | 8 | 10 | 9 | 13 | 10 | 3 | . | . | . | . | . | . | . | . | . | 1 | 2 | 3 | 3 | 2 | 1 | |
| 42 | 21 | 24 | 29 | 32 | 33 | 33 | 28 | 17 | 8 | 8 | 4 | 1 | 1 | . | . | . | 1 | 3 | 3 | 4 | 6 | 10 | 16 | 19 | |
| 47 | 45 | 45 | 45 | 44 | 45 | 44 | 40 | 42 | 38 | 24 | 16 | 12 | 9 | 10 | 7 | 6 | 8 | 13 | 18 | 28 | 37 | 37 | 39 | 44 | |
| 52 | 89 | 93 | 90 | 93 | 94 | 91 | 70 | 59 | 57 | 51 | 45 | 39 | 27 | 25 | 25 | 32 | 41 | 53 | 68 | 73 | 77 | 85 | 86 | 88 | 592 |
| 57 | 151 | 155 | 163 | 158 | 155 | 157 | 162 | 135 | 96 | 80 | 72 | 62 | 62 | 64 | 66 | 63 | 71 | 91 | 110 | 130 | 140 | 149 | 153 | 147 | 1134 |
| 62 | 63 | 53 | 44 | 43 | 41 | 44 | 55 | 83 | 119 | 112 | 103 | 98 | 92 | 77 | 86 | 101 | 106 | 118 | 124 | 104 | 93 | 79 | 72 | 71 | 1274 |
| 67 | 8 | 6 | 5 | 5 | 4 | 4 | 10 | 24 | 35 | 64 | 81 | 86 | 89 | 95 | 95 | 94 | 85 | 52 | 32 | 27 | 19 | 17 | 12 | 9 | 842 |
| 72 | 1 | . | . | . | . | . | 4 | 10 | 18 | 27 | 30 | 44 | 49 | 53 | 43 | 35 | 30 | 31 | 17 | 13 | 7 | 3 | 3 | 2 | 391 |
| 77 | . | . | . | . | . | . | . | 2 | 9 | 13 | 19 | 23 | 25 | 22 | 24 | 21 | 22 | 13 | 8 | 3 | 2 | 1 | . | . | 201 |
| 82 | . | . | . | . | . | . | . | . | 1 | 5 | 11 | 10 | 16 | 21 | 21 | 20 | 13 | 8 | 3 | . | . | . | . | . | 129 |
| 87 | . | . | . | . | . | . | . | . | . | . | 3 | 9 | 10 | 11 | 12 | 8 | 5 | 2 | . | . | . | . | . | . | 60 |
| 92 | . | . | . | . | . | . | . | . | . | . | . | . | 3 | 5 | 4 | 3 | 2 | . | . | . | . | . | . | . | 17 |
| 97 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | 1 | . | . | . | . | . | . | . | . | 4 |
| 102 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| On Hours | | | | | | | 301 | 313 | 335 | 352 | 364 | 371 | 374 | 374 | 377 | 378 | 375 | 368 | 362 | | | | | | 4644.00 |

**HVAC Controls (Site 1911)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | HVAC Controls |
| Site Description | Office |

**Measure Description** Install four Variable Air Volume (VAV) air handlers with Variable Frequency Drives (VFD's), new motors, and four sets of outside and return air ducting, dampers, and actuators.

**Summary of Ex Ante Impact Calculations** Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and all HVAC plant and system characteristics.

**Comments on PG&E Calculations** The correct climate zone, HVAC plant, and building characteristics were used in the application. However, the model appears to have over-estimated the impact of the retrofit. For example, the model results indicate that heating energy is reduced to only 35 therms for an entire year, which is highly unlikely for the area.

**Evaluation Process** The evaluation process consisted of reviewing the application form and supporting documentation and conducting an on-site survey.

The on-site survey was conducted on September 21, 1999 in Walnut Creek (Climate Zone 12). Information on the retrofit equipment and operating conditions were collected through an inspection of the plant and through an interview with the Mechanical Contractor that maintains the equipment.

A printout was provided that listed the setpoints from the buildings Energy Management System (EMS). Also provided were trend logs over a two day period. Due to the complexity of the retrofit, only partial estimates were obtained. The systems that were modeled included the fans, chiller, cooling tower, and boiler. Using the outputs from the DOE2.1E model, realization rates for each system were calculated. These realization rates were leveraged to the entire building to obtain overall energy, demand, and therm impacts.

Discussions provided data for development of a relationship between chiller loading and outdoor dry bulb. The chiller is available from 7:00 am to 7:00 pm on weekdays. Space conditioning is available on weekends by request in two-hour blocks. The Chiller is generally brought on line at 50 degrees outside air temperature. The Mechanical Contractor estimated that the chiller reaches 100% loading at approximately 100 degrees outside air temperature.

To compute the impacts, the following assumptions were used:

- A linear loading strategy was used for the analysis of both the baseline and rebated chillers, which assumed initial loading at 50 degrees and 100% loading at 100 Degrees F.

The cooling tower was modeled using fan horsepower and operating hours. The model was calibrated using ex ante pre-retrofit energy usage and fan horsepower.

The boiler was modeled such that the pre-retrofit scenario allowed the boiler to operate continuously and the post-retrofit scenario shut the boiler down at 80 degrees F outside air temperature. This was calibrated to the pre-retrofit boiler usage claimed in the model using actual weather data and duty cycle.

Fans were modeled using horsepower and operating hours. Again, the model was calibrated using ex ante pre-retrofit energy usage.

Evaluation-based energy and therm impacts were all lower than ex ante estimates. Although no demand impacts were claimed, it appears that the demand actually increased due to the fact that 3 three horsepower motors were replaced with 3 five horsepower motors. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 0 | 94,618.33 | 11,721 |
| **Adjusted Engineering** | 0 | 36,703.29 | 6,710 |
| **Engineering Realization Rate** | N/A | 0.39 | 0.57 |

Site 1911: Overall Results

| | | Ex Post | | | Ex Ante | | |
|---|---|---|---|---|---|---|---|
| | | kW | kWh | Therms | kW | kWh | Therms |
| Fan | Pre-Retrofit | 10.444 | 55018.992 | 0 | | 53826 | |
| | Post-Retrofit | 14.92 | 38024.87328 | 0 | | 38289 | |
| | Impact | -4.476 | 16994.11872 | 0 | 0 | 15537 | 0 |
| | Realization Rate | N/A | 1.094 | N/A | | | |
| Chiller | Pre-Retrofit | 62.11 | 132,543.94 | 0 | | 166105 | |
| | Post-Retrofit | 62.11 | 119,483.83 | 0 | | 97399 | |
| | Impact | 0 | 13060.10987 | 0 | 0 | 68706 | 0 |
| | Realization Rate | N/A | 0.190 | N/A | | | |
| Cooling Tower | Pre-Retrofit | 1.3055 | 6877.374 | 0 | | 6831 | |
| | Post-Retrofit | 1.3055 | 4564.028 | 0 | | 5370 | |
| | Impact | 0 | 2313.346 | 0 | 0 | 1461 | 0 |
| | Realization Rate | N/A | 1.583 | N/A | | | |
| Boiler | Pre-Retrofit | | 4770 | 11,727 | | 4770 | 11756 |
| | Post-Retrofit | | 2040.520338 | 5,017 | | 13 | 35 |
| | Impact | | 2729.479662 | 6710.4 | 0 | 4757 | 11721 |
| | Realization Rate | N/A | 0.574 | 0.573 | | | |
| | | | | | | | |
| Total | Impact | -4.476 | 35097.05425 | 6710.4 | 0 | 90461 | 11721 |
| | Realization Rate | N/A | 0.388 | 0.573 | | | |
| Total Impact With All End Uses | | -4.5 | 36703.3 | 6710.4 | 0 | 94601 | 11721 |

Site 1911: Fan and Cooling Tower Results

| Fans | hp | quantity | total hp | kW | Annual Operating Hours | Annual Energy Use (kWh) | VFD Average % loaded | Adjusted Annual Energy Use (kWh) |
|---|---|---|---|---|---|---|---|---|
| Pre-Retrofit | 3 | 3 | 9 | 6.714 | 5268 | 35369.352 | 1 | 35369.352 |
| Pre-Retrofit | 5 | 1 | 5 | 3.73 | 5268 | 19649.64 | 1 | 19649.64 |
| Pre-Retrofit Totals | | | 14 | 10.444 | 5268 | 55018.992 | 1 | 55018.992 |
| | | | | | | | | |
| Post-Retrofit | 5 | 4 | 20 | 14.92 | 3496 | 52160.32 | 0.9 | 38024.87328 |
| Post-Retrofit Totals | | | 20 | 14.92 | 3496 | 52160.32 | 0.9 | 38024.87328 |
| Impact (kWh) | | | | | | | | 16994.11872 |

| Cooling Tower | hp | quantity | total hp | kW | Annual Operating | Annual Energy Use |
|---|---|---|---|---|---|---|
| Pre-Retrofit | 1.75 | 1 | 1.75 | 1.3055 | 5268.00 | 6877.374 |
| Post-Retrofit | 1.75 | 1 | 1.75 | 1.3055 | 3496.00 | 4564.028 |
| Impact (kWh) | | | | | | 2313.346 |

Site 1911: Fan and Cooling Tower Pre-Retrofit Hours

| Temp | Sun | Mon | Tue | Wed | Thu | Fri | Sat | Total |
|---|---|---|---|---|---|---|---|---|
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 5 |
| 37 | 2 | 18 | 12 | 8 | 3 | 11 | 4 | 58 |
| 42 | 8 | 50 | 25 | 36 | 29 | 37 | 8 | 193 |
| 47 | 28 | 103 | 94 | 66 | 74 | 57 | 25 | 447 |
| 52 | 94 | 141 | 135 | 143 | 155 | 149 | 81 | 898 |
| 57 | 78 | 151 | 133 | 141 | 130 | 133 | 71 | 837 |
| 62 | 56 | 86 | 88 | 127 | 117 | 123 | 57 | 654 |
| 67 | 61 | 88 | 77 | 76 | 88 | 80 | 51 | 521 |
| 72 | 45 | 79 | 69 | 78 | 79 | 66 | 50 | 466 |
| 77 | 41 | 64 | 61 | 51 | 57 | 57 | 26 | 357 |
| 82 | 26 | 49 | 58 | 40 | 30 | 41 | 25 | 269 |
| 87 | 27 | 31 | 31 | 36 | 27 | 41 | 27 | 220 |
| 92 | 24 | 28 | 17 | 17 | 11 | 16 | 23 | 136 |
| 97 | 18 | 33 | 16 | 9 | 18 | 13 | 12 | 119 |
| 102 | 10 | 12 | 9 | 20 | 13 | 5 | 6 | 75 |
| 107 | 2 | 3 | 7 | 0 | 0 | 0 | 1 | 13 |
| 112 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| On Hours | 520 | 936 | 832 | 848 | 832 | 832 | 468 | **5268.00** |

Site 1911: Fan and Cooling Tower Post-Retrofit Hours

| Temp | Sun | Mon | Tue | Wed | Thu | Fri | Sat | Total |
|---|---|---|---|---|---|---|---|---|
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 |
| 37 | 0 | 5 | 5 | 3 | 1 | 4 | 4 | 22 |
| 42 | 0 | 17 | 12 | 16 | 10 | 17 | 6 | 78 |
| 47 | 0 | 54 | 57 | 42 | 47 | 41 | 21 | 262 |
| 52 | 0 | 92 | 98 | 96 | 106 | 100 | 70 | 562 |
| 57 | 0 | 90 | 93 | 107 | 90 | 88 | 51 | 519 |
| 62 | 0 | 60 | 63 | 88 | 86 | 96 | 45 | 438 |
| 67 | 0 | 50 | 63 | 64 | 71 | 68 | 43 | 359 |
| 72 | 0 | 60 | 52 | 64 | 70 | 56 | 34 | 336 |
| 77 | 0 | 55 | 53 | 44 | 52 | 46 | 23 | 273 |
| 82 | 0 | 44 | 55 | 37 | 27 | 34 | 21 | 218 |
| 87 | 0 | 25 | 28 | 32 | 23 | 39 | 22 | 169 |
| 92 | 0 | 25 | 14 | 14 | 9 | 16 | 12 | 90 |
| 97 | 0 | 32 | 15 | 9 | 18 | 13 | 8 | 95 |
| 102 | 0 | 12 | 9 | 20 | 13 | 5 | 3 | 62 |
| 107 | 0 | 3 | 7 | 0 | 0 | 0 | 0 | 10 |
| 112 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| On Hours | 0 | 624 | 624 | 636 | 624 | 624 | 364 | **3496.00** |

Site 1911: Chiller Results

| Post-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.88 |
| Nom. Tons | 80 |
| nom kw | 70.4 |

Pre-Retrofit

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Operating Hours per year (Actual) | Tons Output | Efficiency (kW/Ton) | Peak Demand (kW) | TMY Annual Energy Use (kWh/year) | Actual Annual Energy Use (kWh/year) |
|---|---|---|---|---|---|---|---|
| 107 | 0.00 | 13.00 | 80 | 0.770 | 0.00 | 0.00 | 801.22 |
| 102 | 26.00 | 75.00 | 80 | 0.772 | 61.80 | 1,606.73 | 4,634.81 |
| 97 | 81.00 | 119.00 | 80 | 0.774 | 61.96 | 5,018.38 | 7,372.69 |
| 92 | 165.00 | 136.00 | 80 | 0.776 | 62.11 | 10,247.50 | 8,446.42 |
| 87 | 254.00 | 220.00 | 64 | 0.775 | 49.57 | 12,590.72 | 10,905.35 |
| 82 | 406.00 | 269.00 | 64 | 0.776 | 49.68 | 20,169.37 | 13,363.45 |
| 77 | 423.00 | 357.00 | 64 | 0.778 | 49.78 | 21,057.35 | 17,771.81 |
| 72 | 499.00 | 466.00 | 48 | 0.798 | 38.31 | 19,117.86 | 17,853.56 |
| 67 | 586.00 | 521.00 | 48 | 0.800 | 38.38 | 22,492.09 | 19,997.24 |
| 62 | 722.00 | 654.00 | 32 | 0.876 | 28.04 | 20,243.92 | 18,337.29 |
| Totals | 3162.00 | 2830.00 | | | 62.11 | 132,543.94 | 119,483.83 |

Post-Retrofit

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Operating Hours per year (Actual) | Tons Output | Efficiency (kW/Ton) | Peak Demand (kW) | TMY Annual Energy Use (kWh/year) | Actual Annual Energy Use (kWh/year) |
|---|---|---|---|---|---|---|---|
| 107 | 0.00 | 10.00 | 80 | 0.770 | 0.00 | 0.00 | 616.32 |
| 102 | 26.00 | 64.00 | 64 | 0.769 | 49.21 | 1,279.45 | 3,149.43 |
| 97 | 81.00 | 100.00 | 48 | 0.789 | 37.90 | 3,069.55 | 3,789.57 |
| 92 | 165.00 | 99.00 | 48 | 0.791 | 37.99 | 6,268.00 | 3,760.80 |
| 87 | 252.00 | 175.00 | 48 | 0.793 | 38.08 | 9,595.06 | 6,663.24 |
| 82 | 395.00 | 224.00 | 48 | 0.795 | 38.16 | 15,072.79 | 8,547.61 |
| 77 | 387.00 | 282.00 | 32 | 0.871 | 27.89 | 10,791.65 | 7,863.68 |
| 72 | 439.00 | 346.00 | 32 | 0.873 | 27.94 | 12,265.53 | 9,667.14 |
| 67 | 452.00 | 372.00 | 32 | 0.875 | 27.99 | 12,651.84 | 10,412.58 |
| 62 | 533.00 | 446.00 | 32 | 0.876 | 28.04 | 14,944.61 | 12,505.25 |
| Totals | 2730.00 | 2118.00 | | | 49.21 | 85,938.51 | 66,975.62 |

Site 1911: Chiller Inputs to Model

| Parameter | Value Reported | Units of Parameter | Notes |
|---|---|---|---|
| City | Walnut Creek | | |
| Climate Zone | 12 | | |
| Pre-Retrofit Nominal Chiller Capacity | 80 | Tons | Application |
| Pre-Retrofit Nominal Chiller Efficiency | 0.88 | kW/ton | Dummy Value |
| | | | |
| Post-Retrofit Nominal Chiller Capacity | 80 | Tons | Application |
| Post-Retrofit Nominal Chiller Efficiency | 0.88 | kW/ton | From Chiller Rating Sheet |
| | | | |
| Chiller AM Lockout | 7:00 | AM | Contact provided schedule |
| Chiller PM Lockout | 7:00 | PM | Contact provided schedule |
| Chiller Startup OSA Temperature | 50 | F | Contact provided estimate |
| Chiller Max Load OSA Temperature | 100 | F | Contact provided estimate |

Site 1911: Pre-Retrofit Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.88 |
| Nom. Tons | 80 |
| nom kw | 70.4 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 107 | 80 | 90 | 56 | 78 | 1.000 | 1.00 | 0.88 | 0.2191 | 4.56 | 0.770 |
| 102 | 80 | 89 | 55 | 78 | 1.000 | 1.00 | 0.88 | 0.2197 | 4.55 | 0.772 |
| 97 | 80 | 88 | 54 | 79 | 1.000 | 1.00 | 0.88 | 0.2203 | 4.54 | 0.774 |
| 92 | 80 | 87 | 53 | 79 | 1.000 | 1.00 | 0.88 | 0.2208 | 4.53 | 0.776 |
| 87 | 64 | 86 | 52 | 80 | 0.800 | 0.79 | 0.89 | 0.2203 | 4.54 | 0.775 |
| 82 | 64 | 85 | 51 | 80 | 0.800 | 0.79 | 0.89 | 0.2208 | 4.53 | 0.776 |
| 77 | 64 | 84 | 50 | 80 | 0.800 | 0.79 | 0.89 | 0.2212 | 4.52 | 0.778 |
| 72 | 48 | 83 | 49 | 81 | 0.600 | 0.61 | 0.89 | 0.2270 | 4.41 | 0.798 |
| 67 | 48 | 82 | 48 | 81 | 0.600 | 0.61 | 0.89 | 0.2274 | 4.40 | 0.800 |
| 62 | 32 | 81 | 47 | 81 | 0.400 | 0.44 | 0.90 | 0.2492 | 4.01 | 0.876 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1911: Post-Retrofit Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.88 |
| Nom. Tons | 80 |
| nom kw | 70.4 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 107 | 80 | 90 | 56 | 78 | 1.000 | 1.00 | 0.88 | 0.2191 | 4.56 | 0.770 |
| 102 | 64 | 89 | 55 | 78 | 0.800 | 0.79 | 0.88 | 0.2187 | 4.57 | 0.769 |
| 97 | 48 | 88 | 54 | 79 | 0.600 | 0.61 | 0.88 | 0.2245 | 4.45 | 0.789 |
| 92 | 48 | 87 | 53 | 79 | 0.600 | 0.61 | 0.88 | 0.2251 | 4.44 | 0.791 |
| 87 | 48 | 86 | 52 | 80 | 0.600 | 0.61 | 0.89 | 0.2256 | 4.43 | 0.793 |
| 82 | 48 | 85 | 51 | 80 | 0.600 | 0.61 | 0.89 | 0.2261 | 4.42 | 0.795 |
| 77 | 32 | 84 | 50 | 80 | 0.400 | 0.44 | 0.89 | 0.2478 | 4.03 | 0.871 |
| 72 | 32 | 83 | 49 | 81 | 0.400 | 0.44 | 0.89 | 0.2483 | 4.03 | 0.873 |
| 67 | 32 | 82 | 48 | 81 | 0.400 | 0.44 | 0.89 | 0.2488 | 4.02 | 0.875 |
| 62 | 32 | 81 | 47 | 81 | 0.400 | 0.44 | 0.90 | 0.2492 | 4.01 | 0.876 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 1911: Chiller TMY Weather Data

| Temperature | 12:00 AM | 1:00 AM | 2:00 AM | 3:00 AM | 4:00 AM | 5:00 AM | 6:00 AM | 7:00 AM | 8:00 AM | 9:00 AM | 10:00 AM | 11:00 AM | 12:00 PM | 1:00 PM | 2:00 PM | 3:00 PM | 4:00 PM | 5:00 PM | 6:00 PM | 7:00 PM | 8:00 PM | 9:00 PM | 10:00 PM | 11:00 PM | Pre-Retro | Post-Retro |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | 3 | 3 | 3 | 6 | | | | | | | | | | | | | | | | | | | |
| 32 | 9 | 8 | 12 | 13 | 14 | 15 | 16 | 11 | | | | | | | | | | | | | | 2 | 4 | 7 | | |
| 37 | 20 | 27 | 31 | 34 | 36 | 37 | 34 | 24 | 16 | 7 | | | | | | | | | | 4 | 10 | 15 | 15 | 15 | | |
| 42 | 54 | 61 | 64 | 62 | 61 | 60 | 59 | 46 | 47 | 31 | 18 | 7 | 4 | 4 | 1 | 2 | 3 | 10 | 21 | 26 | 29 | 31 | 44 | 51 | | |
| 47 | 75 | 67 | 70 | 76 | 73 | 62 | 55 | 54 | 39 | 37 | 37 | 30 | 19 | 13 | 15 | 17 | 25 | 32 | 40 | 39 | 49 | 58 | 63 | 70 | | |
| 52 | 72 | 78 | 85 | 85 | 80 | 87 | 59 | 49 | 49 | 52 | 42 | 35 | 31 | 35 | 36 | 31 | 36 | 45 | 52 | 62 | 65 | 76 | 72 | 67 | | |
| 57 | 83 | 78 | 67 | 61 | 68 | 60 | 71 | 55 | 43 | 36 | 48 | 51 | 45 | 43 | 41 | 42 | 45 | 50 | 48 | 55 | 65 | 61 | 80 | 88 | | |
| 62 | 33 | 27 | 22 | 22 | 22 | 31 | 42 | 69 | 48 | 35 | 32 | 35 | 46 | 49 | 46 | 44 | 43 | 36 | 50 | 54 | 62 | 72 | 56 | 44 | 722 | 533 |
| 67 | 14 | 15 | 12 | 9 | 8 | 8 | 17 | 32 | 64 | 52 | 37 | 36 | 31 | 26 | 27 | 28 | 37 | 42 | 40 | 59 | 50 | 29 | 19 | 15 | 586 | 452 |
| 72 | 5 | 4 | 2 | | | 2 | 5 | 18 | 37 | 57 | 44 | 36 | 30 | 33 | 34 | 37 | 32 | 32 | 49 | 33 | 20 | 17 | 10 | 8 | 499 | 439 |
| 77 | | | | | | | 1 | 7 | 14 | 36 | 52 | 47 | 34 | 32 | 31 | 25 | 33 | 48 | 28 | 21 | 14 | 3 | 2 | | 423 | 387 |
| 82 | | | | | | | | | 8 | 14 | 33 | 46 | 58 | 46 | 43 | 47 | 47 | 31 | 22 | 10 | 1 | 1 | | | 406 | 395 |
| 87 | | | | | | | | | | 8 | 15 | 24 | 32 | 40 | 39 | 35 | 28 | 22 | 9 | 2 | | | | | 254 | 252 |
| 92 | | | | | | | | | | | 7 | 14 | 21 | 25 | 27 | 35 | 22 | 9 | 5 | | | | | | 165 | 165 |
| 97 | | | | | | | | | | | | 4 | 14 | 15 | 19 | 13 | 9 | 6 | 1 | | | | | | 81 | 81 |
| 102 | | | | | | | | | | | | | | 4 | 6 | 9 | 5 | 2 | | | | | | | 26 | 26 |
| 107 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0 |
| 112 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0 |
| On Hours | | | | | | 41 | 65 | 126 | 171 | 202 | 220 | 242 | 266 | 270 | 272 | 273 | 256 | 228 | 204 | 179 | 147 | | | | 3162 | 2730 |

Site 1911: Chiller Operating Hours

Pre-Retrofit

Actual temperature by hour from 11/26/97 to 11/25/98

| Temp | Sun | Mon | Tue | Wed | Thu | Fri | Sat | On Hours |
|---|---|---|---|---|---|---|---|---|
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 42 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 47 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 52 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 57 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 62 | 56 | 86 | 88 | 127 | 117 | 123 | 57 | 654 |
| 67 | 61 | 88 | 77 | 76 | 88 | 80 | 51 | 521 |
| 72 | 45 | 79 | 69 | 78 | 79 | 66 | 50 | 466 |
| 77 | 41 | 64 | 61 | 51 | 57 | 57 | 26 | 357 |
| 82 | 26 | 49 | 58 | 40 | 30 | 41 | 25 | 269 |
| 87 | 27 | 31 | 31 | 36 | 27 | 41 | 27 | 220 |
| 92 | 24 | 28 | 17 | 17 | 11 | 16 | 23 | 136 |
| 97 | 18 | 33 | 16 | 9 | 18 | 13 | 12 | 119 |
| 102 | 10 | 12 | 9 | 20 | 13 | 5 | 6 | 75 |
| 107 | 2 | 3 | 7 | 0 | 0 | 0 | 1 | 13 |
| 112 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| On Hours | 310 | 473 | 433 | 454 | 440 | 442 | 278 | **2830.00** |

Post-Retrofit

Actual temperature by hour from 11/26/97 to 11/25/98

| Temp | Sun | Mon | Tue | Wed | Thu | Fri | Sat | On Hours |
|---|---|---|---|---|---|---|---|---|
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 42 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 47 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 52 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 57 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 62 | 8 | 60 | 63 | 88 | 86 | 96 | 45 | 446 |
| 67 | 13 | 50 | 63 | 64 | 71 | 68 | 43 | 372 |
| 72 | 10 | 60 | 52 | 64 | 70 | 56 | 34 | 346 |
| 77 | 9 | 55 | 53 | 44 | 52 | 46 | 23 | 282 |
| 82 | 6 | 44 | 55 | 37 | 27 | 34 | 21 | 224 |
| 87 | 6 | 25 | 28 | 32 | 23 | 39 | 22 | 175 |
| 92 | 9 | 25 | 14 | 14 | 9 | 16 | 12 | 99 |
| 97 | 5 | 32 | 15 | 9 | 18 | 13 | 8 | 100 |
| 102 | 2 | 12 | 9 | 20 | 13 | 5 | 3 | 64 |
| 107 | 0 | 3 | 7 | 0 | 0 | 0 | 0 | 10 |
| 112 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| On Hours | 68 | 366 | 359 | 372 | 369 | 373 | 211 | **2118.00** |

Site 1911: Boiler Results

| Boiler | |
|---|---|
| Nom. Efficiency | 0.8 |
| Nom. Output (kBtuh) | 720 |
| Nom. Input (kBtuh) | 900 |

| Outdoor DB Temperature (F) | Pre-Retrofit Operating Hours per year (Actual) | Post-Retrofit Operating Hours per year (Actual) | Percent of Hour Boiler is Firing | Pre-Retrofit Energy Input (therms) | Post-Retrofit Energy Input (therms) | Annual Energy Savings (Therms/year) |
|---|---|---|---|---|---|---|
| 112 | 0 | 0 | 10% | 0 | 0 | 0 |
| 107 | 13 | 0 | 10% | 12 | 0 | 12 |
| 102 | 75 | 0 | 10% | 68 | 0 | 68 |
| 97 | 119 | 0 | 10% | 107 | 0 | 107 |
| 92 | 136 | 0 | 10% | 122 | 0 | 122 |
| 87 | 220 | 0 | 10% | 198 | 0 | 198 |
| 82 | 269 | 0 | 10% | 242 | 0 | 242 |
| 77 | 357 | 202 | 10% | 321 | 182 | 140 |
| 72 | 466 | 254 | 15% | 629 | 343 | 286 |
| 67 | 521 | 288 | 25% | 1,172 | 648 | 524 |
| 62 | 654 | 308 | 30% | 1,766 | 832 | 934 |
| 57 | 837 | 375 | 30% | 2,260 | 1,013 | 1,247 |
| 52 | 898 | 417 | 30% | 2,425 | 1,126 | 1,299 |
| 47 | 447 | 182 | 35% | 1,408 | 573 | 835 |
| 42 | 193 | 49 | 40% | 695 | 176 | 518 |
| 37 | 58 | 14 | 45% | 235 | 57 | 178 |
| 32 | 14 | 14 | 50% | 63 | 63 | 0 |
| 27 | 1 | 1 | 50% | 5 | 5 | 0 |
| 22 | 0 | 0 | 50% | 0 | 0 | 0 |
| Totals | 5,278 | 2,104 | | 11,727 | 5,017 | 6,710 |

Site 1911: Boiler Pre-Retrofit Operating Hours
Actual temperature by hour from 11/26/97 to 11/25/98

| Temp | Sun | Mon | Tue | Wed | Thu | Fri | Sat | On Hours |
|---|---|---|---|---|---|---|---|---|
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 32 | 0 | 0 | 2 | 0 | 1 | 6 | 5 | 14 |
| 37 | 2 | 18 | 12 | 8 | 3 | 11 | 4 | 58 |
| 42 | 8 | 50 | 25 | 36 | 29 | 37 | 8 | 193 |
| 47 | 28 | 103 | 94 | 66 | 74 | 57 | 25 | 447 |
| 52 | 94 | 141 | 135 | 143 | 155 | 149 | 81 | 898 |
| 57 | 78 | 151 | 133 | 141 | 130 | 133 | 71 | 837 |
| 62 | 56 | 86 | 88 | 127 | 117 | 123 | 57 | 654 |
| 67 | 61 | 88 | 77 | 76 | 88 | 80 | 51 | 521 |
| 72 | 45 | 79 | 69 | 78 | 79 | 66 | 50 | 466 |
| 77 | 41 | 64 | 61 | 51 | 57 | 57 | 26 | 357 |
| 82 | 26 | 49 | 58 | 40 | 30 | 41 | 25 | 269 |
| 87 | 27 | 31 | 31 | 36 | 27 | 41 | 27 | 220 |
| 92 | 24 | 28 | 17 | 17 | 11 | 16 | 23 | 136 |
| 97 | 18 | 33 | 16 | 9 | 18 | 13 | 12 | 119 |
| 102 | 10 | 12 | 9 | 20 | 13 | 5 | 6 | 75 |
| 107 | 2 | 3 | 7 | 0 | 0 | 0 | 1 | 13 |
| 112 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| On Hours | 520 | 936 | 834 | 848 | 832 | 835 | 473 | **5278.00** |

Site 1911: Boiler Post-Retrofit Operating Hours
Actual temperature by hour from 11/26/97 to 11/25/98

| Temp | Sun | Mon | Tue | Wed | Thu | Fri | Sat | On Hours |
|---|---|---|---|---|---|---|---|---|
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 32 | 0 | 0 | 2 | 0 | 1 | 6 | 5 | 14 |
| 37 | 1 | 2 | 2 | 1 | 1 | 3 | 4 | 14 |
| 42 | 4 | 11 | 7 | 8 | 5 | 8 | 6 | 49 |
| 47 | 19 | 30 | 33 | 26 | 24 | 29 | 21 | 182 |
| 52 | 66 | 51 | 55 | 57 | 62 | 56 | 70 | 417 |
| 57 | 54 | 54 | 55 | 61 | 52 | 48 | 51 | 375 |
| 62 | 41 | 34 | 31 | 52 | 52 | 53 | 45 | 308 |
| 67 | 41 | 36 | 41 | 37 | 47 | 43 | 43 | 288 |
| 72 | 36 | 32 | 35 | 39 | 40 | 38 | 34 | 254 |
| 77 | 28 | 33 | 32 | 28 | 29 | 29 | 23 | 202 |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 102 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 107 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 112 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| On Hours | 290 | 283 | 293 | 309 | 313 | 313 | 303 | **2104.00** |

EMS System Upgrade (Site 2332)

| | |
|---|---|
| Program | Advance Performance Options |
| Measure | Customized Controls |
| Site Description | Office |

**Measure Description** Install an energy management system (EMS) to reduce the number of operating hours of equipment.

**Summary of Ex Ante Impact Calculations** Impacts were determined using the Trane Trace 600 building energy simulation model, which models the loading of the heating, cooling and ventilation systems. Impacts were based on the reduced number of operating hours of selected systems to correspond to occupancy schedules. Electricity is saved by reducing the number of operating hours of the hallway lights, compressors, fans and pumps as well as reducing the number of hours the building is conditioned by reset thermostats during unoccupied periods.

**Comments on Calculations** Impact calculations were based on the assumption that retrofits occurred previous to the EMS installation. These retrofits did not occur, resulting in higher ex post impact estimates. Impact calculations were based on the reduction of operating hours and a temperature set back for unoccupied hours. Demand impacts were not included in the application. Appropriate equipment efficiencies, size, cfm and climate zone weather data were used.

**Evaluation Process** The evaluation process consisted of reviewing the application form and supporting documentation, conducting an on-site survey and reviewing the results from the Trane Trace 600 outputs accompanying the application. Pre and post retrofit schedules were confirmed through interviews with the chief engineer. The on-site survey was conducted on June 22, 1999 with the Energy Project Manager.

The engineering calculations consisted of segmenting the end uses into separate models for lighting, chillers, motors, and boilers. All end uses except the boilers were modeled. Due to the lack of usage data for the boilers, the ex ante therm impacts were accepted as accurate. The scheduling for the lights provides demand impacts that were not claimed on the application, therefore, no realization rate can be calculated. Both energy and demand impacts were higher than ex ante claims. This is due to the baseline energy usage being somewhat higher than anticipated, and the EMS providing more efficient use of the equipment than anticipated.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| MDSS | 0.0 | 231,779.46 | 28,782 |
| Adjusted Engineering | 74.68 | 566,551.68 | 28,782 |
| Engineering Realization Rate | N/A | 2.44 | 1.0 |

Site 2332: Overall Results

| | | Energy | Demand | Therms |
|---|---|---|---|---|
| MDSS | | 231,779 | 0 | 28,782 |
| QC | Lighting | 29,481 | 6 | 0 |
| | Boilers | 0 | 0 | 28,782 |
| | Fans | 481,288 | 0 | 0 |
| | Chiller | 55,782 | 69 | 0 |
| | Total | 566,552 | 75 | 28,782 |
| Realization Rate | | 2.44 | N/A | 1.00 |

Site 2332: Boiler Results

| | Energy | Demand | Therms |
|---|---|---|---|
| MDSS | 0 | 0 | 28,782 |
| QC | 0 | 0 | 28,782 |
| Realization Rate | N/A | N/A | 1.00 |

**Note: Assumed accurate from application**

| Site 2332: Fan Results | | | |
|---|---|---|---|
| | Energy | Demand | Therms |
| MDSS | 231,779 | 0 | 28,782 |
| QC | 481,288 | 0 | 28,782 |
| Realization Rate | 2.08 | N/A | 1.00 |

| Fans - kWh | PG&E | QC |
|---|---|---|
| Total | | |
| Base | 3,233,760 | 3,233,760 |
| New | 3,002,023 | 2,752,472 |
| Impact | 275,449 | 481,288 |
| Realization Rate | | 1.75 |
| Note: From calculations below | | |

| PG&E Estimate | | | | | Hours | kWh |
|---|---|---|---|---|---|---|
| | HP | kW/HP | LF | kW | Saved | Saved |
| Pump-CWP1 | 30 | 0.746 | 0.58 | 12.98 | 547.5 | 7106.77 |
| Pump-CWP2 | 30 | 0.746 | 0.58 | 12.98 | 547.5 | 7106.77 |
| Pump-CHWP1 | 30 | 0.746 | 0.58 | 12.98 | 547.5 | 7106.77 |
| Pump-CHWP2 | 30 | 0.746 | 0.58 | 12.98 | 547.5 | 7106.77 |
| Pump-HWP1 | 7.5 | 0.746 | 0.58 | 3.25 | 0 | 0.00 |
| Pump-HWP2 | 7.5 | 0.746 | 0.58 | 3.25 | 0 | 0.00 |
| Pump-HWP3 | 7.5 | 0.746 | 0.58 | 3.25 | 0 | 0.00 |
| Pump-HWP4 | 7.5 | 0.746 | 0.58 | 3.25 | 0 | 0.00 |
| Pump-HWP5 | 7.5 | 0.746 | 0.58 | 3.25 | 0 | 0.00 |
| Pump-HWP6 | 7.5 | 0.746 | 0.58 | 3.25 | 0 | 0.00 |
| AHU-1S | 200 | 0.746 | 0.63 | 94.00 | 1095 | 102925.62 |
| AHU-1R | 40 | 0.746 | 0.63 | 18.80 | 1095 | 20585.12 |
| AHU-2S | 200 | 0.746 | 0.63 | 94.00 | 1095 | 102925.62 |
| AHU-2R | 40 | 0.746 | 0.63 | 18.80 | 1095 | 20585.12 |
| AC-1S | 15 | 0.746 | 0.63 | 7.05 | 0 | 0.00 |
| AC-2S | 15 | 0.746 | 0.63 | 7.05 | 0 | 0.00 |
| | | | | | | 275,448.56 |

| QC Estimate | | | | | | Hours | kWh |
|---|---|---|---|---|---|---|---|
| | HP | kW/HP | LF | Efficiency | kW | Saved | Saved |
| Pump-CWP1 | 30 | 0.746 | 0.58 | 0.86 | 15.09 | 730 | 11018.25 |
| Pump-CWP2 | 30 | 0.746 | 0.58 | 0.86 | 15.09 | 730 | 11018.25 |
| Pump-CHWP1 | 30 | 0.746 | 0.58 | 0.86 | 15.09 | 730 | 11018.25 |
| Pump-CHWP2 | 30 | 0.746 | 0.58 | 0.86 | 15.09 | 730 | 11018.25 |
| Pump-HWP1 | 7.5 | 0.746 | 0.58 | 0.86 | 3.77 | 0 | 0.00 |
| Pump-HWP2 | 7.5 | 0.746 | 0.58 | 0.86 | 3.77 | 0 | 0.00 |
| Pump-HWP3 | 7.5 | 0.746 | 0.58 | 0.86 | 3.77 | 0 | 0.00 |
| Pump-HWP4 | 7.5 | 0.746 | 0.58 | 0.86 | 3.77 | 0 | 0.00 |
| Pump-HWP5 | 7.5 | 0.746 | 0.58 | 0.86 | 3.77 | 0 | 0.00 |
| Pump-HWP6 | 7.5 | 0.746 | 0.58 | 0.86 | 3.77 | 8030 | 30300.18 |
| AHU-1S | 200 | 0.746 | 0.63 | 0.86 | 109.30 | 1460 | 159574.60 |
| AHU-1R | 40 | 0.746 | 0.63 | 0.86 | 21.86 | 1460 | 31914.92 |
| AHU-2S | 200 | 0.746 | 0.63 | 0.86 | 109.30 | 1460 | 159574.60 |
| AHU-2R | 40 | 0.746 | 0.63 | 0.86 | 21.86 | 1460 | 31914.92 |
| AC-1S | 15 | 0.746 | 0.63 | 0.86 | 8.20 | 1460 | 11968.10 |
| AC-2S | 15 | 0.746 | 0.63 | 0.86 | 8.20 | 1460 | 11968.10 |
| | | | | | | | 481,288.41 |

Site 2332: Lighting Results

| | Energy | Demand | Therms |
|---|---|---|---|
| MDSS | 231,779 | 0 | 0 |
| QC | 29,481 | 5.76 | 0 |
| Realization Rate | 0.13 | N/A | N/A |

| **Lighting - kWh** | | | | | Base Usage | | PG&E Usage | | QC Usage | | PG&E Impact | | QC Impact | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Watts per lamp | Lamps per Fixture | Watts per Fixture | Number of Fixtures | Op Hours | kWh per year | Op Hours | kWh per year | Op Hours | kWh per year | Demand (kW) | Energy (kWh) | Demand (kW) | Energy (kWh) |
| 2nd floor Hallway Compact Flourescents | 13 | 2 | 32 | 136 | 6257 | 27231 | 6257 | 27231 | 1184 | 5151 | 0 | 0 | 4.35 | 22080 |
| 2nd floor Lobby 24/7 CF's | 13 | 2 | 32 | 32 | 8760 | 8970 | 8760 | 8970 | 8760 | 8970 | 0 | 0 | 0.00 | 0 |
| 3rd-6th floor Hallway Compact Flourescents | 13 | 2 | 32 | 44 | 6257 | 8810 | 6257 | 8810 | 1001 | 1409 | 0 | 0 | 1.41 | 7401 |
| 3rd-6th floor Lobby 24/7 CF's | 13 | 2 | 32 | 15 | 8760 | 4205 | 8760 | 4205 | 8760 | 4205 | 0 | 0 | 0.00 | 0 |
| Total | | | | | | 49216 | | 49216 | | 19735 | 0 | 0 | 5.76 | 29481 |

Site 2332: Chiller Results

| | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 231,779 | 0 | | |
| QC | 55,782 | 69 | 56,472 | 69 |
| Realization Rate | 0.24 | N/A | | |

| Pre-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.7 |
| Nom. Tons | 370 |
| nom kw | 259 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 97 | 0.00 | 370 | 0.709 | 0.00 | 0.00 | 4.00 | 1,049.54 |
| 92 | 1.00 | 338 | 0.704 | 237.80 | 237.80 | 13.00 | 3,091.44 |
| 87 | 24.00 | 305 | 0.702 | 5,141.67 | 214.24 | 47.00 | 10,069.11 |
| 82 | 58.00 | 273 | 0.702 | 11,117.82 | 191.69 | 98.00 | 18,785.27 |
| 77 | 165.00 | 241 | 0.707 | 28,075.28 | 170.15 | 143.00 | 24,331.91 |
| 72 | 342.00 | 208 | 0.719 | 51,175.70 | 149.64 | 245.00 | 36,660.95 |
| 67 | 503.00 | 176 | 0.740 | 65,458.65 | 130.14 | 493.00 | 64,157.28 |
| 62 | 432.00 | 143 | 0.779 | 48,234.11 | 111.65 | 477.00 | 53,258.49 |
| 57 | 122.00 | 111 | 0.849 | 11,490.71 | 94.19 | 111.00 | 10,454.66 |
| Totals | 1525.00 | | | 209,441.02 | 237.80 | 1,520.00 | 211,404.00 |

| Post-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.7 |
| Nom. Tons | 370 |
| nom kw | 259 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 97 | 0.00 | 370 | 0.501 | 0.00 | 0.00 | 4.00 | 741.13 |
| 92 | 1.00 | 338 | 0.500 | 168.88 | 168.88 | 13.00 | 2,195.42 |
| 87 | 24.00 | 305 | 0.501 | 3,673.76 | 153.07 | 47.00 | 7,194.44 |
| 82 | 58.00 | 273 | 0.505 | 7,996.33 | 137.87 | 98.00 | 13,511.03 |
| 77 | 165.00 | 241 | 0.513 | 20,338.53 | 123.26 | 143.00 | 17,626.73 |
| 72 | 342.00 | 208 | 0.525 | 37,368.12 | 109.26 | 245.00 | 26,769.56 |
| 67 | 503.00 | 176 | 0.545 | 48,221.96 | 95.87 | 493.00 | 47,263.27 |
| 62 | 432.00 | 143 | 0.579 | 35,891.32 | 83.08 | 477.00 | 39,630.00 |
| 62 | 122.00 | 111 | 0.639 | 8,650.44 | 70.91 | 111.00 | 7,870.48 |
| Totals | 1,525.00 | | | 153,658.89 | 168.88 | 1,520.00 | 154,931.59 |

Site 2332: Post-Retrofit Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0 298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.7 |
| Nom. Tons | 370 |
| nom kw | 259 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 97 | 370 | 72 | 52 | 376 | 0.984 | 0.980 | 0.718 | 0.1424 | 7.02 | 0.501 |
| 92 | 338 | 71.9 | 51.8 | 377 | 0.90 | 0.89 | 0.72 | 0.1423 | 7.03 | 0.500 |
| 87 | 305 | 71.8 | 51.5 | 377 | 0.81 | 0.80 | 0.72 | 0.1426 | 7.01 | 0.501 |
| 82 | 273 | 71.6 | 51.3 | 378 | 0.72 | 0.72 | 0.72 | 0.1437 | 6.96 | 0.505 |
| 77 | 241 | 71.5 | 51.0 | 378 | 0.64 | 0.64 | 0.73 | 0.1458 | 6.86 | 0.513 |
| 72 | 208 | 71.4 | 50.8 | 379 | 0.55 | 0.57 | 0.73 | 0.1493 | 6.70 | 0.525 |
| 67 | 176 | 71.3 | 50.5 | 379 | 0.46 | 0.50 | 0.73 | 0.1551 | 6.45 | 0.545 |
| 62 | 143 | 71.1 | 50.3 | 380 | 0.38 | 0.43 | 0.73 | 0.1648 | 6.07 | 0.579 |
| 57 | 111 | 71 | 50 | 380 | 0.29 | 0.36 | 0.73 | 0.1817 | 5.50 | 0.639 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients – Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2332: Pre-Retrofit Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.298620 | 0.029961 | -0.000801 | 0.017363 | -0.000326 | 0.000631 |
| Part Load Efficiency (PLR) | 0.1714927 | 0.5882021 | 0.2373726 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.7 |
| Nom. Tons | 370 |
| nom kw | 259 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR* | COP | kW/Ton |
| 97 | 370 | 85 | 43 | 346 | 1.068 | 1.071 | 1.011 | 0.2017 | 4.96 | 0.709 |
| 92 | 338 | 85 | 43 | 346 | 0.97 | 0.97 | 1.01 | 0.2003 | 4.99 | 0.704 |
| 87 | 305 | 85 | 43 | 346 | 0.88 | 0.87 | 1.01 | 0.1996 | 5.01 | 0.702 |
| 82 | 273 | 85 | 43 | 346 | 0.79 | 0.78 | 1.01 | 0.1998 | 5.01 | 0.702 |
| 77 | 241 | 85 | 43 | 346 | 0.69 | 0.69 | 1.01 | 0.2012 | 4.97 | 0.707 |
| 72 | 208 | 85 | 43 | 346 | 0.60 | 0.61 | 1.01 | 0.2045 | 4.89 | 0.719 |
| 67 | 176 | 85 | 43 | 346 | 0.51 | 0.53 | 1.01 | 0.2106 | 4.75 | 0.740 |
| 62 | 143 | 85 | 43 | 346 | 0.41 | 0.46 | 1.01 | 0.2215 | 4.51 | 0.779 |
| 57 | 111 | 85 | 43 | 346 | 0.32 | 0.38 | 1.01 | 0.2413 | 4.14 | 0.849 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2332: Weather Data

TMY temperature data for climate zone 03

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 32 | 0 | 0 | 1 | 4 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 37 | 6 | 9 | 13 | 13 | 16 | 15 | 18 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 6 | |
| 42 | 28 | 31 | 34 | 46 | 45 | 44 | 38 | 28 | 12 | 5 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 5 | 6 | 7 | 16 | 21 | 26 | |
| 47 | 72 | 77 | 79 | 84 | 71 | 66 | 70 | 65 | 43 | 31 | 12 | 8 | 6 | 3 | 2 | 2 | 2 | 6 | 21 | 32 | 44 | 43 | 48 | 54 | |
| 52 | 120 | 125 | 125 | 116 | 127 | 122 | 104 | 85 | 79 | 68 | 60 | 43 | 26 | 20 | 17 | 21 | 36 | 53 | 68 | 78 | 93 | 107 | 124 | 127 | |
| 57 | 116 | 105 | 100 | 90 | 95 | 106 | 112 | 120 | 104 | 89 | 83 | 79 | 68 | 70 | 80 | 79 | 95 | 108 | 115 | 129 | 129 | 137 | 127 | 125 | 777 |
| 62 | 21 | 17 | 12 | 11 | 9 | 11 | 19 | 58 | 98 | 102 | 91 | 77 | 77 | 83 | 79 | 84 | 91 | 111 | 109 | 99 | 83 | 55 | 35 | 25 | 802 |
| 67 | 2 | 0 | 1 | 1 | 1 | 1 | 3 | 5 | 20 | 56 | 74 | 77 | 72 | 78 | 84 | 78 | 83 | 60 | 38 | 19 | 9 | 4 | 5 | 2 | 644 |
| 72 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 9 | 32 | 61 | 64 | 61 | 58 | 57 | 37 | 19 | 9 | 2 | 0 | 0 | 0 | 0 | 388 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 10 | 21 | 31 | 30 | 28 | 28 | 15 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 169 |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 8 | 13 | 11 | 11 | 9 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 58 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 7 | 5 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 97 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 102 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 107 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 112 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| | | | | | | | | | | | 292 | 314 | 333 | 341 | 345 | 341 | 326 | 304 | 271 | | | | | | 2867.00 |

TMY temperature by hour from 04/16/97 to 10/15/98

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 27 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 32 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 37 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 42 | . | . | 3 | 3 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | . | |
| 47 | 13 | 16 | 17 | 26 | 18 | 11 | 8 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 2 | 5 | 8 | |
| 52 | 63 | 70 | 75 | 75 | 80 | 74 | 61 | 29 | 11 | 5 | 1 | 1 | . | . | . | . | . | . | 7 | 15 | 26 | 37 | 52 | 59 | |
| 57 | 89 | 83 | 77 | 70 | 76 | 87 | 94 | 89 | 56 | 32 | 13 | 5 | 3 | 2 | 2 | 4 | 11 | 31 | 51 | 70 | 79 | 98 | 96 | 94 | 122 |
| 62 | 17 | 14 | 11 | 9 | 8 | 11 | 18 | 58 | 89 | 77 | 58 | 39 | 25 | 27 | 32 | 35 | 61 | 78 | 87 | 80 | 70 | 42 | 25 | 21 | 432 |
| 67 | 2 | . | 1 | 1 | 1 | 1 | 3 | 5 | 20 | 56 | 70 | 62 | 48 | 64 | 67 | 58 | 71 | 62 | 31 | 18 | 8 | 4 | 5 | 2 | 503 |
| 72 | . | 1 | . | . | . | . | . | 2 | 7 | 9 | 30 | 48 | 57 | 53 | 50 | 47 | 32 | 17 | 8 | 1 | . | . | . | . | 342 |
| 77 | . | . | . | . | . | . | . | . | 1 | 5 | 10 | 20 | 31 | 30 | 28 | 26 | 14 | 6 | . | . | . | . | . | . | 165 |
| 82 | . | . | . | . | . | . | . | . | . | . | 2 | 8 | 13 | 11 | 11 | 9 | 4 | . | . | . | . | . | . | . | 58 |
| 87 | . | . | . | . | . | . | . | . | . | . | . | 1 | 7 | 6 | 4 | 5 | 1 | . | . | . | . | . | . | . | 24 |
| 92 | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | 1 |
| 97 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| 102 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| 112 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| | | | | | | | | | | | 183 | 183 | 184 | 184 | 184 | 184 | 184 | 184 | 177 | | | | | | 1647.00 |

Actual temperature by hour from 06/23/98 to 06/22/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 27 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 32 | 1 | 1 | 2 | 2 | 4 | 4 | 4 | 4 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 3 | |
| 37 | 9 | 12 | 11 | 12 | 13 | 13 | 16 | 14 | 5 | . | . | . | . | . | . | . | . | . | 1 | 2 | 4 | 3 | 6 | 5 | |
| 42 | 27 | 32 | 37 | 43 | 47 | 46 | 43 | 26 | 17 | 12 | 7 | 2 | 2 | . | 1 | 1 | 3 | 5 | 7 | 9 | 13 | 20 | 23 | 26 | |
| 47 | 66 | 68 | 70 | 66 | 68 | 63 | 55 | 56 | 50 | 33 | 23 | 18 | 12 | 13 | 10 | 10 | 14 | 25 | 35 | 45 | 52 | 51 | 54 | 57 | |
| 52 | 109 | 107 | 100 | 106 | 102 | 105 | 92 | 80 | 75 | 75 | 63 | 52 | 40 | 38 | 37 | 46 | 59 | 75 | 85 | 94 | 99 | 108 | 105 | 107 | |
| 57 | 98 | 100 | 108 | 100 | 99 | 101 | 101 | 104 | 94 | 88 | 82 | 78 | 79 | 81 | 86 | 84 | 91 | 94 | 111 | 112 | 113 | 111 | 110 | 103 | 786 |
| 62 | 48 | 42 | 34 | 33 | 29 | 30 | 40 | 49 | 73 | 78 | 82 | 87 | 88 | 77 | 88 | 96 | 84 | 81 | 76 | 70 | 62 | 53 | 54 | 55 | 759 |
| 67 | 4 | 1 | 2 | 3 | 3 | 3 | 10 | 23 | 30 | 44 | 69 | 61 | 63 | 69 | 60 | 66 | 66 | 43 | 27 | 18 | 16 | 16 | 9 | 7 | 493 |
| 72 | 3 | 2 | 1 | . | . | . | 4 | 8 | 15 | 20 | 19 | 31 | 36 | 37 | 30 | 28 | 27 | 21 | 15 | 13 | 5 | 3 | 3 | 2 | 244 |
| 77 | . | . | . | . | . | . | . | 1 | 4 | 10 | 20 | 19 | 18 | 19 | 23 | 18 | 13 | 15 | 7 | 2 | 1 | . | . | . | 152 |
| 82 | . | . | . | . | . | . | . | . | 2 | 5 | 9 | 10 | 14 | 19 | 19 | 16 | 15 | 4 | 1 | . | . | . | . | . | 107 |
| 87 | . | . | . | . | . | . | . | . | . | . | 1 | 7 | 9 | 8 | 7 | 6 | 3 | 2 | . | . | . | . | . | . | 43 |
| 92 | . | . | . | . | . | . | . | . | . | . | . | . | 3 | 3 | 3 | 3 | 1 | . | . | . | . | . | . | . | 13 |
| 97 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | 1 | . | . | . | . | . | . | . | . | 4 |
| 102 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| 112 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| On Hours | | | | | | | | | | | 272 | 293 | 311 | 314 | 317 | 308 | 289 | 260 | 237 | | | | | | 2601.00 |

Actual temperature by hour from 04/16/97 to 10/15/98

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 27 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 32 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 37 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 42 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 47 | . | 1 | 3 | 4 | 5 | 2 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 52 | 25 | 30 | 32 | 34 | 32 | 34 | 22 | 3 | 3 | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 3 | 7 | 12 | 17 | 21 | |
| 57 | 104 | 105 | 109 | 108 | 111 | 112 | 105 | 89 | 46 | 23 | 13 | 7 | 6 | 6 | 4 | 2 | 8 | 20 | 45 | 64 | 84 | 96 | 101 | 101 | 111 |
| 62 | 46 | 43 | 35 | 33 | 32 | 31 | 41 | 57 | 83 | 75 | 58 | 48 | 38 | 30 | 34 | 45 | 57 | 78 | 89 | 88 | 72 | 57 | 51 | 49 | 477 |
| 67 | 5 | 2 | 3 | 4 | 3 | 4 | 11 | 25 | 29 | 50 | 61 | 63 | 57 | 57 | 61 | 64 | 60 | 44 | 26 | 12 | 13 | 14 | 10 | 10 | 493 |
| 72 | 3 | 2 | 1 | . | . | . | 4 | 8 | 15 | 19 | 20 | 27 | 36 | 41 | 35 | 28 | 27 | 20 | 11 | 13 | 5 | 3 | 4 | 2 | 245 |
| 77 | . | . | . | . | . | . | | 1 | 5 | 10 | 18 | 18 | 19 | 18 | 19 | 18 | 13 | 12 | 8 | 3 | 2 | 1 | . | . | 143 |
| 82 | . | . | . | . | . | . | . | . | 2 | 5 | 10 | 11 | 11 | 16 | 16 | 14 | 12 | 6 | 2 | . | . | . | . | . | 98 |
| 87 | . | . | . | . | . | . | . | . | . | . | 1 | 7 | 10 | 9 | 9 | 6 | 3 | 2 | . | . | . | . | . | . | 47 |
| 92 | . | . | . | . | . | . | . | . | . | . | . | . | 3 | 3 | 3 | 3 | 1 | . | . | . | . | . | . | . | 13 |
| 97 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | 1 | . | . | . | . | . | . | . | . | 4 |
| 102 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| 112 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| On Hours | | | | | | | | | | | 181 | 181 | 181 | 181 | 182 | 181 | 181 | 182 | 181 | | | | | | 1631.00 |

**Chiller & Cooling Tower Replacement (Site 2386)**

| | |
|---|---|
| Program | Retrofit Efficiency Options Program |
| Measure | High Efficiency Water-Cooled Chiller and Oversized Cooling Tower |
| Site Description | Community Service |

**Measure Description**

Replace existing water-cooled chiller with a 200-ton high-efficiency water-cooled chiller and replace cooling tower with an oversized cooling tower.

**Summary of Ex Ante Impact Calculations**

Tables of standard values were developed using the HBSSM simulation program based on climate zone, chiller size, building type, chiller efficiency, condenser water temperature, wet-bulb temperature, and cooling tower approach temperature. Values from these tables are used to calculate the rebate and associated impacts.

**Comments on PG&E Calculations**

The application calculations used the correct climate zone, chiller size, cooling tower approach temperature, fan horsepower, and building characteristics.

**Evaluation Process**

The evaluation process consists of a review of the application form and supporting documentation, conducting an on-site survey and then computing impacts using the on-site data. Models are calibrated with actual weather, observed chiller run hours since the installation, chiller loading under extreme outdoor temperature conditions, chilled water temperature, and condenser water temperature. Energy impacts are based on typical weather data. A Title 24 baseline, nominal efficiency, and typical year bin weather data for the applicable climate zone are used in the bin analysis.

The on-site survey was conducted on July 30, 1999 in Fairfield (Climate Zone 12). Information on the retrofit equipment and operating conditions was collected through an inspection of the chillers and through an interview with the Plant Operator.

Discussions provided data for development of a relationship between chiller loading and outdoor dry bulb. The chiller is available 24 hours per day, 7 days per week, including holidays. The contact claims that the chiller is brought on line at 68 degrees outside air temperature. The contact is unsure of the outside air temperature required for full loading, but estimated it at approximately 100 degrees F.

To compute the impacts, the following assumptions were used:

- A linear loading strategy was used for the analysis of both the baseline, and rebated chillers, which assumed initial loading at 70 degrees and 100% loading at 100 degrees. The initial loading temperature was adjusted in order to calibrate the model to actual weather data.

- Based on a water-cooled chiller between 150 and 300 tons, a baseline Title 24 efficiency of 0.837 KW/ton was used.

- The post-retrofit cooling tower approach temperature was 4.14 degrees. The baseline for the cooling tower retrofit was assumed to be the post-retrofit chiller with an approach temperature of 10 degrees.

- The new cooling tower provides energy savings of 0.01 kW/ton for each degree decrease in approach temperature.

Chiller efficiencies at various temperatures were calculated from updated default performance coefficients provided in a memo to the California Energy Commission titled "1995 Proposed Changes to the ACM Manual Central Plant Cooling Equipment" by Mark Hydeman. These coefficients were used to develop a chiller efficiency curve for the Rebate case and a Title 24 base case. Both evaluation-based energy and demand impacts were lower than Ex Ante estimates. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 77.56 | 282,803.31 | 0 |
| **Adjusted Engineering** | 58.73 | 93,901.31 | 0 |
| **Engineering Realization Rate** | 0.76 | 0.33 | N/A |

Site 2386: Results

| Overall Results | Energy | Demand |
|---|---|---|
| MDSS | 282,803 | 77.559 |
| QC | 93,901 | 59 |
| Realization Rate | 0.33 | 0.76 |

| Chiller | Energy | Demand |
|---|---|---|
| MDSS | 210,879 | 67.77 |
| QC | 79,928 | 48 |
| Realization Rate | 0.38 | 0.71 |

| Cooling Tower | Energy | Demand |
|---|---|---|
| MDSS | 71,925 | 9.789 |
| QC | 13,974 | 10.548 |
| Realization Rate | 0.19 | 1.08 |

| Pre-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.8 |
| Nom. Tons | 200 |
| nom kw | 160 |

| Outdoor DB Temperature (F) | Operating Hours per year (Actual) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 112 | 0.00 | 200 | 0.812 | 0.00 | 0.00 |
| 107 | 5.00 | 180 | 0.805 | 724.18 | 144.84 |
| 102 | 30.00 | 160 | 0.804 | 3,861.50 | 128.72 |
| 97 | 78.00 | 140 | 0.815 | 8,896.29 | 114.05 |
| 92 | 176.00 | 120 | 0.840 | 17,749.82 | 100.85 |
| 87 | 335.00 | 100 | 0.891 | 29,850.32 | 89.11 |
| 82 | 433.00 | 80 | 0.985 | 34,128.02 | 78.82 |
| 77 | 537.00 | 60 | 1.166 | 37,583.41 | 69.99 |
| 72 | 581.00 | 40 | 1.565 | 36,379.79 | 62.62 |
| 67 | 0.00 | 20 | 2.835 | 0.00 | 0.00 |
| Totals | 2175.00 | | | 169,173.33 | 144.84 |

| Post-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.571 |
| Nom. Tons | 200 |
| nom kw | 114.2 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) |
|---|---|---|---|---|---|---|
| 112 | 0.00 | 200 | 0.580 | 0.00 | 0.00 | 0.00 |
| 107 | 5.00 | 180 | 0.574 | 516.88 | 103.38 | 5.00 |
| 102 | 96.00 | 160 | 0.574 | 8,819.67 | 91.87 | 30.00 |
| 97 | 216.00 | 140 | 0.581 | 17,583.86 | 81.41 | 78.00 |
| 92 | 345.00 | 120 | 0.600 | 24,833.99 | 71.98 | 176.00 |
| 87 | 418.00 | 100 | 0.636 | 26,584.38 | 63.60 | 335.00 |
| 82 | 544.00 | 80 | 0.703 | 30,603.30 | 56.26 | 433.00 |
| 77 | 606.00 | 60 | 0.833 | 30,271.97 | 49.95 | 537.00 |
| 72 | 722.00 | 40 | 1.117 | 32,267.65 | 44.69 | 581.00 |
| 67 | 0.00 | 20 | 2.024 | 0.00 | 0.00 | 0.00 |
| Totals | 2,952.00 | | | 171,481.70 | 103.38 | 2,175.00 |

| Title 24 Baseline Chiller | |
|---|---|
| Nom. Eff | 0.837 |
| Nom. Tons | 200 |
| nom kw | 167.429 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 112 | 0.00 | 200 | 0.850 | 0.00 | 0.00 |
| 107 | 5.00 | 180 | 0.842 | 757.80 | 151.56 |
| 102 | 96.00 | 160 | 0.842 | 12,930.51 | 134.69 |
| 97 | 216.00 | 140 | 0.853 | 25,779.69 | 119.35 |
| 92 | 345.00 | 120 | 0.879 | 36,409.10 | 105.53 |
| 87 | 418.00 | 100 | 0.932 | 38,975.35 | 93.24 |
| 82 | 544.00 | 80 | 1.031 | 44,867.48 | 82.48 |
| 77 | 606.00 | 60 | 1.221 | 44,381.72 | 73.24 |
| 72 | 722.00 | 40 | 1.638 | 47,307.59 | 65.52 |
| 67 | 0.00 | 20 | 2.967 | 0.00 | 0.00 |
| Totals | 2,952.00 | | | 251,409.24 | 151.56 |

| Post-Retrofit Chiller w/ Cooling Tower | |
|---|---|
| Nom. Eff | 0.571 |
| Nom. Tons | 200 |
| nom kw | 114.2 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) |
|---|---|---|---|---|---|---|
| 112 | 0.00 | 200 | 0.521 | 0.00 | 0.00 | 0.00 |
| 107 | 5.00 | 180 | 0.516 | 464.14 | 92.83 | 5.00 |
| 102 | 96.00 | 160 | 0.516 | 7,919.57 | 82.50 | 30.00 |
| 97 | 216.00 | 140 | 0.523 | 15,811.80 | 73.20 | 78.00 |
| 92 | 345.00 | 120 | 0.541 | 22,407.95 | 64.95 | 176.00 |
| 87 | 418.00 | 100 | 0.577 | 24,134.90 | 57.74 | 335.00 |
| 82 | 544.00 | 80 | 0.645 | 28,053.03 | 51.57 | 433.00 |
| 77 | 606.00 | 60 | 0.774 | 28,141.27 | 46.44 | 537.00 |
| 72 | 722.00 | 40 | 1.059 | 30,575.28 | 42.35 | 581.00 |
| 67 | 0.00 | 20 | 1.965 | 0.00 | 0.00 | 0.00 |
| Totals | 2,952.00 | | | 157,507.94 | 92.83 | 2,175.00 |

Site 2386: Inputs to Model

| Parameter | Value Reported | Units of Parameter | Notes |
|---|---|---|---|
| City | Fairfield | | |
| Climate Zone | 12 | | |
| Pre-Retrofit Nominal Chiller Capacity | 200 | Tons | Application |
| Pre-Retrofit Nominal Chiller Efficiency | 0.800 | kW/ton | Estimated |
| Post-Retrofit Nominal Chiller Capacity | 200 | Tons | Application |
| Post-Retrofit Nominal Chiller Efficiency | 0.571 | kW/ton | From Chiller Rating Sheet |
| Baseline Chiller Efficiency | 0.837 | kW/ton | Title 24 Nominal Efficiency for Chiller >= 150 Tons and < 300 Tons |
| | | | |
| Pre-Retrofit Cooling Tower Approach Temperature | 10.0 | F | Application |
| Post-Retrofit Cooling Tower Approach Temperature | 4.14 | F | Application |
| | | | |
| Chiller AM Lockout | 0:00 | AM | Contact provided schedule |
| Chiller PM Lockout | 0:00 | PM | Contact provided schedule |
| Chiller Startup OSA Temperature | 68 | F | Contact provided estimate |
| Chiller Max Load OSA Temperature | 100 | F | Contact provided estimate |
| Chilled Water Supply Temperature Setpoint | 47 | F | Contact provided setpoints |
| Condenser Water Temperature Setpoint | 87 | F | Contact provided setpoints |
| Date of Chiller Installation | 7/31/97 | | Contact provided estimate |
| Date at Run Hour Reading | 10/31/99 | | Chiller Log |
| Number of Days Chiller Operated | 822 | days | = ((Read Date - Install Date) * 5/7) - 10 Holidays |
| Run Hours for Chiller | 5366 | hours | Documented from Chiller Log |
| Average Hours per Year of Chiller Operation | 2382.71 | Hours/Year | = (Run Hours for New Chiller / Number of Days Chiller Operated) * 365 Days/Year * 5/7 |
| | | | |
| Predicted Run Hours Since Install Using Actual Weather & Setpoints | 5420.00 | hours | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |
| Predicted Hours per Year Using Actual Weather Data & Setpoints | 2175.00 | Hours/Year | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |

Site 2386: Post-Retrofit Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

| Post-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.571 |
| Nom. Tons | 200 |
| nom kw | 114.2 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 200 | 87 | 47 | 209 | 1.000 | 1.03 | 0.99 | 0.1649 | 6.07 | 0.580 |
| 107 | 180 | 87 | 47 | 209 | 0.900 | 0.92 | 0.99 | 0.1633 | 6.12 | 0.574 |
| 102 | 160 | 87 | 47 | 209 | 0.800 | 0.81 | 0.99 | 0.1633 | 6.12 | 0.574 |
| 97 | 140 | 87 | 47 | 209 | 0.700 | 0.72 | 0.99 | 0.1654 | 6.05 | 0.581 |
| 92 | 120 | 87 | 47 | 209 | 0.600 | 0.64 | 0.99 | 0.1706 | 5.86 | 0.600 |
| 87 | 100 | 87 | 47 | 209 | 0.500 | 0.56 | 0.99 | 0.1809 | 5.53 | 0.636 |
| 82 | 80 | 87 | 47 | 209 | 0.400 | 0.50 | 0.99 | 0.2000 | 5.00 | 0.703 |
| 77 | 60 | 87 | 47 | 209 | 0.300 | 0.44 | 0.99 | 0.2368 | 4.22 | 0.833 |
| 72 | 40 | 87 | 47 | 209 | 0.200 | 0.40 | 0.99 | 0.3178 | 3.15 | 1.117 |
| 67 | 20 | 87 | 47 | 209 | 0.100 | 0.36 | 0.99 | 0.5755 | 1.74 | 2.024 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |
| EIRFPLR | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2386: Baseline Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

Post-Retrofit Chiller

| | |
|---|---|
| Nom. Eff | 0.837 |
| Nom. Tons | 200.000 |
| nom kw | 167.428571 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 200 | 87 | 47 | 209 | 1.000 | 1.03 | 0.99 | 0.2417 | 4.14 | 0.850 |
| 107 | 180 | 87 | 47 | 209 | 0.900 | 0.92 | 0.99 | 0.2395 | 4.18 | 0.842 |
| 102 | 160 | 87 | 47 | 209 | 0.800 | 0.81 | 0.99 | 0.2394 | 4.18 | 0.842 |
| 97 | 140 | 87 | 47 | 209 | 0.700 | 0.72 | 0.99 | 0.2425 | 4.12 | 0.853 |
| 92 | 120 | 87 | 47 | 209 | 0.600 | 0.64 | 0.99 | 0.2501 | 4.00 | 0.879 |
| 87 | 100 | 87 | 47 | 209 | 0.500 | 0.56 | 0.99 | 0.2652 | 3.77 | 0.932 |
| 82 | 80 | 87 | 47 | 209 | 0.400 | 0.50 | 0.99 | 0.2932 | 3.41 | 1.031 |
| 77 | 60 | 87 | 47 | 209 | 0.300 | 0.44 | 0.99 | 0.3472 | 2.88 | 1.221 |
| 72 | 40 | 87 | 47 | 209 | 0.200 | 0.40 | 0.99 | 0.4659 | 2.15 | 1.638 |
| 67 | 20 | 87 | 47 | 209 | 0.100 | 0.36 | 0.99 | 0.8438 | 1.19 | 2.967 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |
| EIRFPLR | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2386: Pre-Retrofit Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

Post-Retrofit Chiller

| | |
|---|---|
| Nom. Eff | 0.8 |
| Nom. Tons | 200 |
| nom kw | 160 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 200 | 87 | 47 | 209 | 1.000 | 1.03 | 0.99 | 0.2310 | 4.33 | 0.812 |
| 107 | 180 | 87 | 47 | 209 | 0.900 | 0.92 | 0.99 | 0.2289 | 4.37 | 0.805 |
| 102 | 160 | 87 | 47 | 209 | 0.800 | 0.81 | 0.99 | 0.2288 | 4.37 | 0.804 |
| 97 | 140 | 87 | 47 | 209 | 0.700 | 0.72 | 0.99 | 0.2317 | 4.32 | 0.815 |
| 92 | 120 | 87 | 47 | 209 | 0.600 | 0.64 | 0.99 | 0.2390 | 4.18 | 0.840 |
| 87 | 100 | 87 | 47 | 209 | 0.500 | 0.56 | 0.99 | 0.2534 | 3.95 | 0.891 |
| 82 | 80 | 87 | 47 | 209 | 0.400 | 0.50 | 0.99 | 0.2802 | 3.57 | 0.985 |
| 77 | 60 | 87 | 47 | 209 | 0.300 | 0.44 | 0.99 | 0.3318 | 3.01 | 1.166 |
| 72 | 40 | 87 | 47 | 209 | 0.200 | 0.40 | 0.99 | 0.4452 | 2.25 | 1.565 |
| 67 | 20 | 87 | 47 | 209 | 0.100 | 0.36 | 0.99 | 0.8063 | 1.24 | 2.835 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |
| EIRFPLR | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2386- Weather Data

TMY temperature data for climate zone 12

| Temp | 0.00 | 1:00 | 2:00 | 3.00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15.00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | 1 | 3 | 3 | | | | | | | | | | | | | | | | | | |
| 32 | 4 | 6 | 10 | 14 | 15 | 18 | 19 | 7 | | | | | | | | | | | | | 2 | 4 | 4 | 4 | |
| 37 | 27 | 32 | 34 | 34 | 37 | 32 | 31 | 26 | 17 | 8 | 1 | | | | | | | 2 | 5 | 7 | 6 | 9 | 17 | 26 | |
| 42 | 41 | 40 | 36 | 41 | 37 | 42 | 43 | 34 | 24 | 19 | 13 | 8 | 3 | 3 | 3 | 3 | 5 | 7 | 10 | 19 | 27 | 31 | 32 | 32 | |
| 47 | 50 | 54 | 64 | 65 | 65 | 55 | 48 | 45 | 38 | 24 | 20 | 15 | 11 | 9 | 9 | 8 | 14 | 19 | 29 | 26 | 33 | 42 | 49 | 50 | |
| 52 | 61 | 61 | 61 | 59 | 56 | 53 | 49 | 48 | 49 | 49 | 41 | 35 | 25 | 24 | 21 | 23 | 30 | 45 | 41 | 59 | 58 | 60 | 56 | 55 | |
| 57 | 43 | 42 | 41 | 44 | 48 | 42 | 38 | 39 | 36 | 39 | 46 | 46 | 42 | 41 | 41 | 39 | 42 | 42 | 49 | 43 | 47 | 37 | 44 | 50 | |
| 62 | 35 | 44 | 52 | 63 | 55 | 46 | 39 | 36 | 37 | 35 | 36 | 37 | 39 | 38 | 43 | 37 | 41 | 38 | 40 | 38 | 36 | 40 | 29 | 33 | |
| 67 | 53 | 52 | 40 | 21 | 33 | 47 | 48 | 39 | 37 | 31 | 26 | 27 | 36 | 39 | 31 | 36 | 33 | 32 | 28 | 25 | 22 | 28 | 39 | 39 | 842 |
| 72 | 33 | 26 | 22 | 23 | 17 | 20 | 27 | 41 | 42 | 37 | 33 | 33 | 26 | 23 | 27 | 25 | 24 | 27 | 25 | 32 | 33 | 37 | 47 | 42 | 722 |
| 77 | 15 | 8 | 6 | 1 | 1 | 6 | 18 | 35 | 39 | 41 | 39 | 36 | 29 | 30 | 27 | 26 | 25 | 24 | 32 | 30 | 43 | 42 | 29 | 26 | 606 |
| 82 | 3 | | | 0 | | | 2 | 13 | 33 | 45 | 44 | 35 | 39 | 36 | 35 | 35 | 30 | 35 | 28 | 38 | 39 | 27 | 18 | 9 | 544 |
| 87 | | | | | | | | 2 | 12 | 31 | 38 | 42 | 39 | 31 | 27 | 29 | 38 | 27 | 42 | 38 | 17 | 8 | 1 | | 418 |
| 92 | | | | | | | | | 1 | 6 | 25 | 38 | 37 | 39 | 42 | 43 | 39 | 37 | 26 | 12 | 2 | | | | 345 |
| 97 | | | | | | | | | | | 3 | 15 | 31 | 38 | 36 | 31 | 27 | 27 | 10 | | | | | | 216 |
| 102 | | | | | | | | | | | | | 8 | 15 | 22 | 27 | 19 | 6 | | | | | | | 96 |
| 107 | | | | | | | | | | | | | | 1 | 1 | 3 | | | | | | | | | 5 |
| 112 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| On Hours | 72 | 55 | 43 | 32 | 31 | 45 | 66 | 107 | 142 | 172 | 192 | 208 | 223 | 227 | 229 | 233 | 213 | 195 | 174 | 158 | 143 | 125 | 111 | 91.6 | 2952.00 |

Actual temperature by hour from 07/31/97 to 10/31/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | . | . | . | . | . | . | 1 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 27 | 2 | 3 | 2 | 3 | 3 | 5 | 4 | 4 | 2 | . | . | . | . | . | . | . | . | . | . | . | . | . | 2 | 3 | |
| 32 | 8 | 8 | 9 | 10 | 13 | 15 | 15 | 15 | 7 | 5 | 1 | . | . | . | . | . | . | . | . | 1 | 2 | 6 | 5 | 6 | |
| 37 | 27 | 36 | 42 | 48 | 48 | 51 | 48 | 37 | 33 | 18 | 13 | 11 | 6 | 4 | 3 | 2 | 3 | 6 | 10 | 13 | 16 | 13 | 21 | 23 | |
| 42 | 67 | 70 | 80 | 87 | 87 | 81 | 80 | 67 | 49 | 33 | 22 | 10 | 11 | 10 | 8 | 9 | 10 | 12 | 11 | 19 | 30 | 40 | 41 | 58 | |
| 47 | 124 | 119 | 117 | 126 | 126 | 128 | 116 | 100 | 89 | 84 | 60 | 46 | 31 | 24 | 25 | 25 | 31 | 43 | 65 | 71 | 90 | 100 | 114 | 121 | |
| 52 | 138 | 160 | 166 | 169 | 173 | 170 | 158 | 133 | 121 | 127 | 122 | 98 | 87 | 82 | 71 | 75 | 86 | 102 | 123 | 135 | 128 | 128 | 130 | 131 | |
| 57 | 171 | 170 | 188 | 181 | 190 | 186 | 158 | 119 | 100 | 64 | 82 | 111 | 119 | 119 | 117 | 120 | 115 | 107 | 97 | 101 | 105 | 132 | 146 | 165 | |
| 62 | 136 | 129 | 116 | 112 | 108 | 120 | 138 | 153 | 117 | 103 | 76 | 72 | 66 | 74 | 84 | 77 | 78 | 81 | 74 | 103 | 138 | 147 | 143 | 137 | |
| 67 | 88 | 75 | 63 | 55 | 44 | 31 | 57 | 104 | 142 | 122 | 95 | 62 | 63 | 60 | 62 | 58 | 54 | 58 | 100 | 112 | 103 | 100 | 110 | 98 | 1916 |
| 72 | 32 | 29 | 26 | 22 | 26 | 31 | 29 | 48 | 78 | 123 | 118 | 103 | 85 | 69 | 61 | 62 | 73 | 87 | 88 | 87 | 91 | 78 | 61 | 42 | 1546 |
| 77 | 22 | 20 | 12 | 10 | 6 | 4 | 18 | 28 | 48 | 68 | 110 | 113 | 104 | 89 | 76 | 81 | 74 | 82 | 83 | 84 | 61 | 43 | 29 | 27 | 1291 |
| 82 | 8 | 4 | 2 | 2 | 1 | 1 | 1 | 13 | 24 | 43 | 58 | 90 | 92 | 90 | 92 | 84 | 91 | 81 | 60 | 44 | 30 | 23 | 16 | 12 | 982 |
| 87 | . | . | . | . | . | . | . | 1 | 11 | 26 | 40 | 54 | 80 | 94 | 93 | 93 | 86 | 69 | 38 | 27 | 23 | 11 | 5 | . | 749 |
| 92 | . | . | . | . | . | . | . | . | 2 | 6 | 23 | 34 | 40 | 50 | 65 | 64 | 54 | 48 | 27 | 21 | 6 | 2 | . | . | 440 |
| 97 | . | . | . | . | . | . | . | . | . | 1 | 5 | 16 | 28 | 38 | 40 | 40 | 39 | 24 | 23 | 5 | . | . | . | . | 259 |
| 102 | . | . | . | . | . | . | . | . | . | . | . | 3 | 10 | 17 | 20 | 28 | 21 | 20 | 5 | . | . | . | . | . | 122 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 3 | 6 | 7 | 8 | 8 | 1 | . | . | . | . | . | 31 |
| 112 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| On Hours | 97 | 83 | 65 | 56 | 49 | 48 | 71 | 132 | 220 | 316 | 390 | 438 | 465 | 474 | 478 | 480 | 468 | 437 | 383 | 313 | 252 | 197 | 155 | 120 | 5420.00 |

Actual temperature by hour from 11/01/98 to 10/31/99

| Temp | 0:00 | 1:00 | 2.00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | . | . | . | . | . | . | 1 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 27 | 2 | 3 | 2 | 3 | 3 | 5 | 3 | 4 | 2 | . | . | . | . | . | . | . | . | . | . | . | . | . | 2 | 3 | |
| 32 | 8 | 8 | 7 | 8 | 10 | 13 | 14 | 12 | 6 | 5 | 1 | . | . | . | . | . | . | . | . | 1 | 2 | 6 | 5 | 6 | |
| 37 | 21 | 28 | 31 | 35 | 36 | 38 | 30 | 25 | 24 | 14 | 12 | 11 | 6 | 4 | 3 | 2 | 3 | 6 | 10 | 13 | 15 | 11 | 15 | 17 | |
| 42 | 37 | 33 | 44 | 43 | 41 | 39 | 43 | 35 | 26 | 22 | 16 | 7 | 8 | 9 | 7 | 8 | 9 | 10 | 8 | 11 | 17 | 25 | 27 | 35 | |
| 47 | 60 | 57 | 55 | 60 | 63 | 56 | 51 | 51 | 45 | 41 | 30 | 27 | 16 | 13 | 13 | 13 | 15 | 21 | 30 | 36 | 45 | 49 | 57 | 57 | |
| 52 | 56 | 70 | 69 | 71 | 72 | 73 | 61 | 46 | 60 | 55 | 49 | 38 | 39 | 35 | 28 | 31 | 39 | 45 | 55 | 63 | 60 | 59 | 53 | 57 | |
| 57 | 67 | 64 | 80 | 77 | 82 | 80 | 76 | 44 | 23 | 34 | 47 | 56 | 58 | 58 | 60 | 58 | 53 | 55 | 55 | 49 | 42 | 52 | 58 | 63 | |
| 62 | 65 | 62 | 48 | 42 | 34 | 45 | 56 | 83 | 55 | 27 | 23 | 33 | 36 | 36 | 41 | 39 | 41 | 32 | 21 | 31 | 48 | 58 | 68 | 67 | |
| 67 | 31 | 25 | 19 | 17 | 16 | 9 | 16 | 41 | 67 | 60 | 37 | 16 | 15 | 19 | 23 | 23 | 18 | 17 | 35 | 50 | 55 | 54 | 46 | 37 | 746 |
| 72 | 10 | 8 | 5 | 5 | 6 | 6 | 9 | 10 | 33 | 65 | 58 | 44 | 31 | 25 | 18 | 16 | 23 | 38 | 41 | 43 | 39 | 29 | 20 | 14 | 581 |
| 77 | 5 | 5 | 3 | 2 | 1 | 2 | 4 | 8 | 14 | 32 | 64 | 54 | 49 | 38 | 30 | 38 | 34 | 38 | 43 | 36 | 24 | 13 | 7 | 5 | 537 |
| 82 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 4 | 6 | 10 | 23 | 44 | 46 | 42 | 46 | 38 | 42 | 43 | 35 | 17 | 10 | 6 | 5 | 4 | 433 |
| 87 | . | . | . | . | . | . | . | 1 | 3 | 8 | 10 | 22 | 38 | 50 | 46 | 48 | 43 | 30 | 16 | 7 | 7 | 4 | 2 | . | 335 |
| 92 | . | . | . | . | . | . | . | . | 1 | 2 | 7 | 8 | 13 | 22 | 30 | 30 | 25 | 21 | 8 | 7 | 1 | 1 | . | . | 176 |
| 97 | . | . | . | . | . | . | . | . | . | . | 1 | 4 | 8 | 9 | 12 | 15 | 14 | 7 | 7 | 1 | . | . | . | . | 78 |
| 102 | . | . | . | . | . | . | . | . | . | . | . | 1 | 2 | 4 | 6 | 7 | 4 | 6 | 1 | . | . | . | . | . | 30 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | 2 | . | . | . | . | . | . | . | 5 |
| 112 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| On Hours | 30 | 25 | 18 | 16 | 14 | 13 | 20 | 39 | 84 | 131 | 165 | 183 | 193 | 199 | 199 | 200 | 194 | 186 | 165 | 131 | 103 | 74.6 | 52.4 | 37.8 | 2175.00 |

**Boiler Replacement (Site 2387)**

| | |
|---|---|
| Program | Retrofit Efficiency Options Program |
| Measure | High Efficiency Gas Boiler for Space Heating |
| Site Description | Community Service |

**Measure Description** Replace 2 gas boilers with energy efficient gas boilers for space heating.

**Summary of Ex Ante Impact Calculations** Tables of standard values were developed using the HBSSM simulation program based on climate zone, boiler size, building type, and boiler efficiency. Values from these tables are used to calculate the rebate and associated impacts.

**Comments on PG&E Calculations** The correct climate zone, building, and boiler characteristics were used in the application. The account information, however, is linked to the animal shelter rather than the detention facility. The monthly billing data does not add up to the annual total used in the application, but the error is not proliferated in subsequent calculations.

**Evaluation Process** The evaluation process consisted of reviewing the application form and supporting documentation and conducting an on-site survey. The on-site survey was conducted on July 30, 1999. Information on the retrofit equipment and operating conditions were collected through an inspection of the boilers and through an interview with the Plant Operator.

Because the Plant Operator is responsible for several other sites, there was limited information regarding the operating schedule for the boilers. The boilers are available 24 hours per day, 7 days per week to provide space heating. The setpoint is 170 degrees F. Due to the lack of scheduling information, the inputs to the rebate calculation were verified and impacts claimed in the application are deemed reasonable.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| MDSS | 0 | 0 | 2506.76 |
| Adjusted Engineering | 0 | 0 | 2506.76 |
| Engineering Realization Rate | N/A | N/A | 1.0 |

**Heat Exchanger (Site 2404)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | Plate and Frame Heat Exchanger |
| Site Description | College |

**Measure Description** Install a plate and frame heat exchanger to recharge a thermal energy storage (TES) system.

**Summary of Ex Ante Impact Calculations** A Spreadsheet model was developed which calculates the energy usage of the TES system both with and without the heat exchanger based on wet bulb temperatures, tank size, cooling requirements, chiller size and cooling tower size. Values from this model are used to calculate the rebate and associated impacts.

**Comments on PG&E Calculations** The correct wet bulb temperature data, approach temperatures, chiller size, and operating schedule were used in the application, but the motor efficiencies, load factors, and chiller efficiencies were slightly different. In addition, the chilled water temperature is lower than originally anticipated. The baseline for this project is the pre-retrofit chiller plant.

**Evaluation Process** The evaluation process consisted of reviewing the application form and supporting documentation and conducting an on-site survey.

The on-site survey was conducted on August 11, 1999 in Fresno (Climate Zone 13). Information on the retrofit equipment and operating conditions were collected through an inspection of the cooling tower and through an interview with the Chief Engineer and Director of Plant Operations.

The model used for the ex ante rebate calculations was obtained and examined for discrepancies. After correcting the chilled water temperature, chiller efficiency, motor efficiency, and load factor, the model was run again. The ex post energy impact result is slightly higher than the ex ante estimate.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 0 | 365,434.95 | 0 |
| **Adjusted Engineering** | 0 | 373,247.54 | 0 |
| **Engineering Realization Rate** | N/A | 1.02 | N/A |

Site 2404: Inputs to Model

| | |
|---|---|
| Tower Approach | 3 |
| HX Approach | 2 |
| Free Cool Flow | 1500 |
| Campus Return | 57 |
| Campus Differential | 7 |
| Indoor set point | 72 |
| base cool load | 330 |
| Mech Cooling kW | 628 |
| Free Cooling kW | 198 |
| required wbt | 45 |
| Min Allowable TES tonhr Capacity | 8000 |
| Chiller Temp | 39 |
| Chiller Flow | 1100 |
| Initial TES tonhrs | 7670 |
| Initial Remaining gallons | 612976 |
| Initial total gallons withdrawn | 1024924 |
| Initial TES Temperature | 39 |

| | Mech | Free |
|---|---|---|
| **Primary CW Pumps Running =** | **1** | **1** |
| **Cooling Tower Pumps Running =** | **1** | **1** |
| **Cooling Tower Fans Running =** | **1** | **2** |
| **Chillers Running =** | **1** | **0** |

**Table 3**
**Energy Cost Savings for the Free Cooling Project at UC Fresno**

| | ENERGY CONSUMPTION COMPARISON | | | | | | | ENERGY COST SAVINGS | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Month | Energy Consumption - Mech. Cooling | | | Energy Consumption - Free Cooling | | | Energy Savings - Free Cooling | Mechanical Cooling | Free Cooling | Cost Savings |
| | Off-Peak (kWhr) | Partial Peak (kWhr) | Total (kWhr) | Off-Peak (kWhr) | Partial Peak (kWhr) | Total (kWhr) | Total (kWhr) | Total ($) | Total ($) | Total ($) |
| Nov | 71,087 | 100,010 | 171,097 | 63,754 | 68,345 | 132,100 | 38,998 | $8,307 | $6,333 | $1,974 |
| Dec | 77,869 | 109,017 | 186,886 | 34,183 | 33,647 | 67,830 | 119,055 | $9,071 | $2,974 | $6,097 |
| Jan | 77,869 | 109,017 | 186,886 | 37,762 | 50,440 | 88,202 | 98,684 | $9,071 | $4,091 | $4,980 |
| Feb | 70,333 | 98,467 | 168,800 | 53,369 | 45,908 | 99,277 | 69,523 | $8,193 | $4,574 | $3,619 |
| Mar | 67,821 | 95,695 | 163,516 | 54,647 | 61,882 | 116,528 | 46,988 | $7,940 | $5,537 | $2,403 |
| Total | 364,980 | 512,205 | 877,185 | 243,715 | 260,223 | 503,937 | 373,248 | $42,582 | $23,509 | $19,073 |

*Assumptions:*

| | |
|---|---|
| Off-Peak TES Charging Only = | no |
| Off & Partial Peak TES Charging = | yes |
| Max WBT for Free Cooling = | 45 |

# Table 2. Daily Winter Cooling Profiles and Energy Consumption

*Assumptions:*

| | | | |
|---|---|---|---|
| Free Cooling Mode = | yes | Primary CW Pumps Running = | 1 |
| Off-Peak TES Charging Only = | no | Cooling Tower Pumps Running = | 1 |
| Off & Partial Peak TES Charging = | yes | Cooling Tower Fans Running = | 2 |
| Max WBT for Free Cooling = | 45 | Chillers Running = | 0 |

| Day | Free Cooling Availability (tonhrs) | Campus Cooling Load (tonhrs) | Free Cooling Used (tonhrs) | TES Capacity (tonhrs) | TES Temp (F) | Off-Peak Chiller/Aux (kWhr) | Off-Peak Free Cooling (kWhr) | Partial Peak Chiller/Aux (kWhr) | Partial Peak Free Cooling (kWhr) | Total (kWhr) |
|---|---|---|---|---|---|---|---|---|---|---|
| 28-Oct | | | | | | | | | | |
| 29-Oct | | | | | | | | | | |
| 30-Oct | | | | | | | | | | |
| 31-Oct | | | | | | | | | | |
| 1-Nov | 0 | 7920 | 0 | 12574 | 39 | 0 | 0 | 0 | 0 | 0 |
| 2-Nov | 2438 | 7920 | 2437 | 7732 | 42 | 488 | 992 | 0 | 0 | 1480 |
| 3-Nov | 1750 | 7920 | 1749 | 7735 | 42 | 1496 | 794 | 3201 | 0 | 5492 |
| 4-Nov | 3625 | 7920 | 3624 | 7755 | 44 | 997 | 1191 | 2285 | 198 | 4671 |
| 5-Nov | 2188 | 7920 | 2187 | 8253 | 45 | 1745 | 595 | 2996 | 397 | 5734 |
| 6-Nov | 5438 | 7920 | 5435 | 7997 | 46 | 244 | 1786 | 1447 | 198 | 3676 |
| 7-Nov | 3313 | 7920 | 3311 | 7782 | 45 | 752 | 1389 | 2590 | 0 | 4731 |
| 8-Nov | 0 | 7920 | 0 | 7721 | 42 | 2491 | 0 | 3491 | 0 | 5982 |
| 9-Nov | 8250 | 7920 | 8247 | 9372 | 46 | 250 | 1786 | 751 | 1191 | 3977 |
| 10-Nov | 5125 | 7920 | 5063 | 7801 | 46 | 769 | 1389 | 205 | 175 | 2538 |
| 11-Nov | 0 | 7920 | 0 | 7729 | 42 | 2485 | 0 | 3489 | 0 | 5974 |
| 12-Nov | 4250 | 7920 | 4248 | 7925 | 44 | 748 | 1389 | 2192 | 198 | 4528 |
| 13-Nov | 6375 | 7920 | 6372 | 7771 | 45 | 701 | 1389 | 354 | 595 | 3040 |
| 14-Nov | 5813 | 7920 | 5810 | 7779 | 45 | 712 | 1389 | 894 | 595 | 3591 |
| 15-Nov | 4625 | 7920 | 4623 | 7785 | 45 | 1073 | 992 | 1438 | 794 | 4296 |
| 16-Nov | 0 | 7920 | 0 | 7725 | 42 | 2493 | 0 | 3490 | 0 | 5983 |
| 17-Nov | 438 | 7920 | 437 | 7801 | 41 | 2250 | 198 | 3503 | 0 | 5951 |
| 18-Nov | 4875 | 7920 | 4873 | 7883 | 44 | 498 | 1588 | 1864 | 198 | 4148 |
| 19-Nov | 7250 | 7920 | 7247 | 8133 | 46 | 147 | 1786 | 565 | 595 | 3093 |
| 20-Nov | 7375 | 7920 | 7372 | 8179 | 46 | 338 | 1786 | 107 | 397 | 2628 |
| 21-Nov | 5875 | 7920 | 5873 | 7903 | 46 | 482 | 1588 | 861 | 198 | 3129 |
| 22-Nov | 2813 | 7920 | 2811 | 7772 | 44 | 747 | 992 | 3039 | 198 | 4977 |
| 23-Nov | 0 | 7920 | 0 | 7715 | 41 | 2493 | 0 | 3493 | 0 | 5986 |
| 24-Nov | 0 | 7920 | 0 | 7688 | 40 | 2502 | 0 | 3505 | 0 | 6008 |
| 25-Nov | 5000 | 7920 | 4998 | 7956 | 44 | 500 | 1588 | 1924 | 198 | 4210 |
| 26-Nov | 5375 | 7920 | 5373 | 7776 | 45 | 754 | 1389 | 1043 | 397 | 3583 |
| 27-Nov | 0 | 7920 | 0 | 7717 | 41 | 2492 | 0 | 3492 | 0 | 5984 |
| 28-Nov | 0 | 7920 | 0 | 7689 | 40 | 2502 | 0 | 3505 | 0 | 6007 |
| 29-Nov | 3875 | 7920 | 3873 | 7753 | 43 | 924 | 1191 | 2201 | 397 | 4713 |
| 30-Nov | 0 | 7920 | 0 | 7705 | 41 | 2496 | 0 | 3497 | 0 | 5992 |
| 1-Dec | 0 | 7920 | 0 | 7684 | 40 | 2504 | 0 | 3508 | 0 | 6012 |
| 2-Dec | 4688 | 7920 | 4686 | 7755 | 44 | 747 | 1389 | 1765 | 397 | 4298 |
| 3-Dec | 1813 | 7920 | 1812 | 8535 | 43 | 1745 | 595 | 3496 | 0 | 5837 |
| 4-Dec | 17500 | 7920 | 13386 | 14018 | 44 | 0 | 1637 | 0 | 1831 | 3468 |
| 5-Dec | 18750 | 7920 | 7766 | 13873 | 45 | 0 | 830 | 0 | 1142 | 1973 |
| 6-Dec | 19938 | 7920 | 8325 | 14288 | 44 | 0 | 833 | 0 | 1156 | 1989 |
| 7-Dec | 20813 | 7920 | 8231 | 14610 | 44 | 0 | 798 | 0 | 1080 | 1878 |
| 8-Dec | 16125 | 7920 | 6849 | 13346 | 45 | 0 | 811 | 0 | 1110 | 1921 |
| 9-Dec | 15063 | 7920 | 7011 | 12446 | 46 | 0 | 905 | 0 | 1304 | 2209 |
| 10-Dec | 15375 | 7920 | 8678 | 13215 | 45 | 0 | 1229 | 0 | 732 | 1961 |
| 11-Dec | 14250 | 7920 | 7815 | 13119 | 45 | 0 | 1274 | 0 | 602 | 1877 |
| 12-Dec | 15313 | 7920 | 8196 | 13405 | 45 | 0 | 1071 | 0 | 1076 | 2147 |
| 13-Dec | 7938 | 7920 | 3426 | 8914 | 45 | 0 | 603 | 0 | 168 | 771 |
| 14-Dec | 8125 | 7920 | 8122 | 9565 | 46 | 0 | 1786 | 335 | 992 | 3113 |
| 15-Dec | 12125 | 7920 | 10580 | 12238 | 46 | 0 | 1951 | 0 | 864 | 2814 |
| 16-Dec | 11000 | 7920 | 6803 | 11129 | 46 | 0 | 1303 | 0 | 664 | 1967 |
| 17-Dec | 8250 | 7920 | 5649 | 8884 | 47 | 0 | 1540 | 0 | 188 | 1728 |
| 18-Dec | 10125 | 7920 | 9326 | 10282 | 46 | 0 | 1985 | 0 | 604 | 2588 |
| 19-Dec | 18375 | 7920 | 10669 | 13044 | 45 | 0 | 1441 | 0 | 1389 | 2830 |
| 20-Dec | 28688 | 7920 | 11363 | 16502 | 42 | 0 | 816 | 0 | 1058 | 1875 |
| 21-Dec | 32813 | 7920 | 10832 | 19427 | 40 | 0 | 672 | 0 | 901 | 1573 |
| 22-Dec | 36813 | 7920 | 10474 | 21994 | 37 | 0 | 577 | 0 | 775 | 1352 |
| 23-Dec | 33938 | 7920 | 8859 | 22944 | 37 | 0 | 524 | 0 | 716 | 1241 |
| 24-Dec | 31563 | 7920 | 8011 | 23045 | 36 | 0 | 508 | 0 | 699 | 1206 |
| 25-Dec | 27375 | 7920 | 7069 | 22202 | 37 | 0 | 515 | 0 | 716 | 1231 |
| 26-Dec | 25625 | 7920 | 6889 | 21179 | 38 | 0 | 536 | 0 | 746 | 1282 |
| 27-Dec | 23813 | 7920 | 6718 | 19985 | 39 | 0 | 562 | 0 | 783 | 1346 |
| 28-Dec | 20063 | 7920 | 6296 | 18367 | 41 | 0 | 599 | 0 | 829 | 1429 |
| 29-Dec | 19875 | 7920 | 6710 | 17165 | 42 | 0 | 648 | 0 | 894 | 1542 |
| 30-Dec | 15250 | 7920 | 5950 | 15202 | 43 | 0 | 701 | 0 | 965 | 1665 |
| 31-Dec | 5313 | 7920 | 2101 | 9384 | 44 | 0 | 545 | 0 | 161 | 706 |
| 1-Jan | 6813 | 7920 | 6810 | 10033 | 46 | 284 | 794 | 1049 | 1588 | 3714 |
| 2-Jan | 16563 | 7920 | 10295 | 12421 | 46 | 0 | 1597 | 0 | 1250 | 2847 |
| 3-Jan | 19125 | 7920 | 8676 | 13187 | 45 | 0 | 915 | 0 | 1242 | 2157 |
| 4-Jan | 20938 | 7920 | 8935 | 14213 | 44 | 0 | 861 | 0 | 1170 | 2031 |
| 5-Jan | 22813 | 7920 | 9073 | 15377 | 43 | 0 | 801 | 0 | 1091 | 1892 |
| 6-Jan | 24875 | 7920 | 9046 | 16514 | 42 | 0 | 736 | 0 | 992 | 1727 |
| 7-Jan | 24313 | 7920 | 8492 | 17097 | 42 | 0 | 699 | 0 | 964 | 1663 |
| 8-Jan | 24875 | 7920 | 8450 | 17637 | 41 | 0 | 678 | 0 | 941 | 1619 |
| 9-Jan | 26500 | 7920 | 8667 | 18395 | 41 | 0 | 655 | 0 | 903 | 1558 |
| 10-Jan | 27375 | 7920 | 8511 | 18997 | 40 | 0 | 626 | 0 | 852 | 1478 |
| 11-Jan | 24438 | 7920 | 7552 | 18637 | 40 | 0 | 619 | 0 | 853 | 1472 |
| 12-Jan | 23625 | 7920 | 7414 | 18140 | 41 | 0 | 630 | 0 | 864 | 1495 |
| 13-Jan | 20375 | 7920 | 6799 | 17028 | 42 | 0 | 655 | 0 | 903 | 1559 |
| 14-Jan | 17438 | 7920 | 6753 | 15869 | 43 | 0 | 693 | 0 | 931 | 1624 |
| 15-Jan | 7500 | 7920 | 2821 | 10772 | 43 | 0 | 519 | 0 | 303 | 822 |
| 16-Jan | 0 | 7920 | 0 | 7721 | 42 | 749 | 0 | 2957 | 0 | 3707 |
| 17-Jan | 0 | 7920 | 0 | 7690 | 40 | 2501 | 0 | 3504 | 0 | 6005 |
| 18-Jan | 0 | 7920 | 0 | 7678 | 39 | 2507 | 0 | 3512 | 0 | 6019 |
| 19-Jan | 0 | 7920 | 0 | 7673 | 39 | 2510 | 0 | 3515 | 0 | 6025 |

# Table 2. Daily Winter Cooling Profiles and Energy Consumption

*Assumptions:*

| | | | |
|---|---|---|---|
| **Free Cooling Mode =** | yes | Primary CW Pumps Running = | 1 |
| Off-Peak TES Charging Only = | no | Cooling Tower Pumps Running = | 1 |
| Off & Partial Peak TES Charging = | yes | Cooling Tower Fans Running = | 2 |
| Max WBT for Free Cooling = | 45 | Chillers Running = | 0 |

| Day | Free Cooling Availability (tonhrs) | Campus Cooling Load (tonhrs) | Free Cooling Used (tonhrs) | TES Capacity (tonhrs) | TES Temp (F) | Off-Peak Chiller/Aux (kWhr) | Off-Peak Free Cooling (kWhr) | Partial Peak Chiller/Aux (kWhr) | Partial Peak Free Cooling (kWhr) | Total (kWhr) |
|---|---|---|---|---|---|---|---|---|---|---|
| 20-Jan | 0 | 7920 | 0 | 7671 | 39 | 2511 | 0 | 3516 | 0 | 6027 |
| 21-Jan | 938 | 7920 | 937 | 7949 | 42 | 2009 | 397 | 3516 | 0 | 5923 |
| 22-Jan | 6125 | 7920 | 6123 | 7766 | 44 | 741 | 1389 | 482 | 595 | 3207 |
| 23-Jan | 3500 | 7920 | 3499 | 8088 | 46 | 498 | 1588 | 3109 | 0 | 5195 |
| 24-Jan | 12125 | 7920 | 10308 | 11103 | 47 | 468 | 1103 | 0 | 2404 | 3974 |
| 25-Jan | 21063 | 7920 | 10177 | 13373 | 45 | 0 | 994 | 0 | 1315 | 2308 |
| 26-Jan | 14875 | 7920 | 6717 | 12177 | 46 | 0 | 893 | 0 | 1262 | 2155 |
| 27-Jan | 18563 | 7920 | 8750 | 13018 | 45 | 0 | 940 | 0 | 1307 | 2247 |
| 28-Jan | 18250 | 7920 | 8361 | 13469 | 45 | 0 | 869 | 0 | 1149 | 2019 |
| 29-Jan | 14500 | 7920 | 7975 | 13534 | 45 | 0 | 1188 | 0 | 800 | 1988 |
| 30-Jan | 12125 | 7920 | 6634 | 12255 | 46 | 0 | 880 | 0 | 1206 | 2086 |
| 31-Jan | 6813 | 7920 | 4359 | 8698 | 47 | 0 | 1264 | 0 | 395 | 1659 |
| 1-Feb | 12938 | 7920 | 11065 | 11857 | 46 | 0 | 1985 | 0 | 1013 | 2997 |
| 2-Feb | 13688 | 7920 | 8095 | 12042 | 46 | 0 | 1312 | 0 | 840 | 2152 |
| 3-Feb | 9563 | 7920 | 5517 | 9646 | 46 | 0 | 1326 | 0 | 271 | 1597 |
| 4-Feb | 8313 | 7920 | 7067 | 8801 | 47 | 0 | 1955 | 0 | 391 | 2346 |
| 5-Feb | 7875 | 7920 | 7184 | 8266 | 47 | 0 | 1985 | 147 | 362 | 2493 |
| 6-Feb | 4875 | 7920 | 4873 | 7813 | 46 | 766 | 1389 | 1205 | 397 | 3757 |
| 7-Feb | 0 | 7920 | 0 | 7736 | 42 | 2483 | 0 | 3487 | 0 | 5970 |
| 8-Feb | 0 | 7920 | 0 | 7697 | 40 | 2498 | 0 | 3501 | 0 | 5999 |
| 9-Feb | 8688 | 7920 | 8684 | 12422 | 44 | 1753 | 595 | 1253 | 1786 | 5388 |
| 10-Feb | 20563 | 7920 | 10825 | 15341 | 43 | 0 | 1362 | 0 | 1035 | 2396 |
| 11-Feb | 19813 | 7920 | 7527 | 14957 | 44 | 0 | 762 | 0 | 1047 | 1809 |
| 12-Feb | 15438 | 7920 | 6464 | 13509 | 45 | 0 | 797 | 0 | 1100 | 1897 |
| 13-Feb | 8188 | 7920 | 3528 | 9120 | 45 | 0 | 602 | 0 | 253 | 855 |
| 14-Feb | 4938 | 7920 | 4936 | 8121 | 46 | 247 | 1588 | 1261 | 198 | 3293 |
| 15-Feb | 6875 | 7920 | 6872 | 7770 | 45 | 524 | 1389 | 0 | 595 | 2508 |
| 16-Feb | 3438 | 7920 | 3436 | 7776 | 45 | 1018 | 1191 | 2397 | 198 | 4804 |
| 17-Feb | 0 | 7920 | 0 | 7718 | 42 | 2493 | 0 | 3492 | 0 | 5985 |
| 18-Feb | 0 | 7920 | 0 | 7689 | 40 | 2502 | 0 | 3505 | 0 | 6006 |
| 19-Feb | 5563 | 7920 | 5560 | 8108 | 45 | 747 | 1389 | 1364 | 794 | 4293 |
| 20-Feb | 5938 | 7920 | 5935 | 7781 | 45 | 752 | 1389 | 505 | 397 | 3043 |
| 21-Feb | 9813 | 7920 | 9809 | 10008 | 48 | 248 | 1786 | 0 | 1985 | 4018 |
| 22-Feb | 8500 | 7920 | 5200 | 7932 | 47 | 486 | 1071 | 0 | 306 | 1863 |
| 23-Feb | 7375 | 7920 | 7372 | 7970 | 46 | 440 | 1588 | 0 | 595 | 2622 |
| 24-Feb | 4813 | 7920 | 4811 | 7783 | 45 | 744 | 1389 | 1476 | 198 | 3808 |
| 25-Feb | 938 | 7920 | 937 | 8005 | 44 | 1992 | 397 | 3490 | 0 | 5880 |
| 26-Feb | 6750 | 7920 | 6747 | 7779 | 45 | 715 | 1389 | 0 | 794 | 2898 |
| 27-Feb | 4063 | 7920 | 4061 | 7769 | 44 | 1003 | 1191 | 1924 | 198 | 4316 |
| 28-Feb | 4375 | 7920 | 4373 | 7770 | 44 | 746 | 1389 | 1950 | 198 | 4284 |
| 1-Mar | 0 | 7920 | 0 | 7715 | 41 | 2493 | 0 | 3493 | 0 | 5986 |
| 2-Mar | 1875 | 6311 | 1874 | 7727 | 42 | 1749 | 595 | 3158 | 198 | 5701 |
| 3-Mar | 938 | 7920 | 937 | 7973 | 42 | 1999 | 397 | 3503 | 0 | 5898 |
| 4-Mar | 14375 | 7920 | 11879 | 11947 | 46 | 0 | 1680 | 0 | 2201 | 3881 |
| 5-Mar | 10938 | 7920 | 6663 | 10698 | 47 | 0 | 1266 | 0 | 872 | 2138 |
| 6-Mar | 7688 | 7920 | 5378 | 8514 | 48 | 0 | 1458 | 268 | 517 | 2243 |
| 7-Mar | 10625 | 7920 | 9609 | 10214 | 48 | 0 | 1901 | 0 | 1328 | 3229 |
| 8-Mar | 6375 | 7920 | 3554 | 7805 | 46 | 751 | 780 | 735 | 216 | 2482 |
| 9-Mar | 7875 | 7920 | 7872 | 10468 | 46 | 1071 | 992 | 986 | 1786 | 4835 |
| 10-Mar | 15125 | 7920 | 8978 | 11538 | 47 | 0 | 1330 | 0 | 1304 | 2635 |
| 11-Mar | 9375 | 7920 | 6030 | 9654 | 47 | 0 | 1299 | 0 | 695 | 1994 |
| 12-Mar | 7688 | 7920 | 5976 | 8111 | 47 | 300 | 1537 | 0 | 198 | 2034 |
| 13-Mar | 5875 | 8507 | 5873 | 8177 | 46 | 215 | 1786 | 1836 | 198 | 4035 |
| 14-Mar | 5438 | 7920 | 5435 | 7890 | 46 | 504 | 1588 | 1164 | 198 | 3454 |
| 15-Mar | 6625 | 7920 | 6622 | 8433 | 47 | 0 | 1985 | 1395 | 794 | 4173 |
| 16-Mar | 4000 | 7920 | 3932 | 7766 | 47 | 646 | 1389 | 1879 | 367 | 4280 |
| 17-Mar | 4688 | 7920 | 4686 | 7786 | 45 | 748 | 1389 | 1725 | 198 | 4061 |
| 18-Mar | 1313 | 7920 | 1312 | 7750 | 43 | 1743 | 595 | 3259 | 0 | 5597 |
| 19-Mar | 875 | 7920 | 875 | 7922 | 43 | 1996 | 397 | 3497 | 0 | 5890 |
| 20-Mar | 1750 | 7920 | 1749 | 7641 | 43 | 1109 | 794 | 3524 | 0 | 5427 |
| 21-Mar | 3625 | 7920 | 3624 | 7746 | 43 | 905 | 1191 | 2290 | 0 | 4386 |
| 22-Mar | 3438 | 7920 | 3436 | 7760 | 44 | 996 | 1191 | 2424 | 198 | 4809 |
| 23-Mar | 0 | 7920 | 0 | 7709 | 41 | 2495 | 0 | 3495 | 0 | 5990 |
| 24-Mar | 1938 | 7920 | 1937 | 7726 | 42 | 1499 | 794 | 3066 | 0 | 5359 |
| 25-Mar | 0 | 7920 | 0 | 7692 | 40 | 2500 | 0 | 3503 | 0 | 6003 |
| 26-Mar | 0 | 7920 | 0 | 7678 | 39 | 2507 | 0 | 3511 | 0 | 6018 |
| 27-Mar | 6938 | 7920 | 6935 | 8554 | 46 | 502 | 1588 | 908 | 992 | 3990 |
| 28-Mar | | | | | | | | | | 0 |
| 29-Mar | | | | | | | | | | |
| 30-Mar | | | | | | | | | | |
| 31-Mar | | | | | | | | | | |
| 1-Apr | | | | | | | | | | |
| 2-Apr | | | | | | | | | | |
| 3-Apr | | | | | | | | | | |
| 4-Apr | | | | | | | | | | |
| 5-Apr | | | | | | | | | | |
| 6-Apr | | | | | | | | | | |
| 7-Apr | | | | | | | | | | |
| 8-Apr | | | | | | | | | | |
| Total | 1,411,875 | 1,165,218 | 782,540 | 1,572,971 | | 105,223 | 138,492 | 176,263 | 83,960 | 503,937 |

# Table 2. Daily Winter Cooling Profiles and Energy Consumption

*Assumptions:*

| | | | |
|---|---|---|---|
| **Free Cooling Mode =** | **yes** | Primary CW Pumps Running = | 1 |
| Off-Peak TES Charging Only = | no | Cooling Tower Pumps Running = | 1 |
| Off & Partial Peak TES Charging = | yes | Cooling Tower Fans Running = | 2 |
| Max WBT for Free Cooling = | 45 | Chillers Running = | 0 |

| Day | Free Cooling Availability (tonhrs) | Campus Cooling Load (tonhrs) | Free Cooling Used (tonhrs) | TES Capacity (tonhrs) | TES Temp (F) | Off-Peak Chiller/Aux (kWhr) | Off-Peak Free Cooling (kWhr) | Partial Peak Chiller/Aux (kWhr) | Partial Peak Free Cooling (kWhr) | Total (kWhr) |
|---|---|---|---|---|---|---|---|---|---|---|
| MONTHLY TOTALS | | | | | | | | | | |
| Nov | 96,063 | 237,600 | 95,964 | 241,086 | 43 | 38,567 | 27,188 | 61,423 | 6,922 | 132,100 |
| Dec | 536,688 | 245,520 | 228,400 | 447,727 | 43 | 4,996 | 29,187 | 9,104 | 24,543 | 67,830 |
| Jan | 436,438 | 245,520 | 192,134 | 394,178 | 43 | 14,779 | 22,983 | 25,160 | 25,280 | 88,202 |
| Feb | 203,313 | 221,760 | 150,879 | 259,189 | 45 | 22,153 | 31,215 | 30,956 | 14,952 | 99,277 |
| Mar | 139,375 | 214,818 | 115,164 | 230,793 | 45 | 26,727 | 27,920 | 49,619 | 12,263 | 116,528 |
| Total | 1,411,875 | 1,165,218 | 782,540 | 1,572,971 | 44 | 105,223 | 138,492 | 176,263 | 83,960 | 503,937 |

# Table 2. Daily Winter Cooling Profiles and Energy Consumption

*Assumptions:*

**Free Cooling Mode =** no
Off-Peak TES Charging Only = no
Off & Partial Peak TES Charging = yes
Max WBT for Free Cooling = 45

Primary CW Pumps Running = 1
Cooling Tower Pumps Running = 1
Cooling Tower Fans Running = 1
Chillers Running = 1

| Day | Free Cooling Availability (tonhrs) | Campus Cooling Load (tonhrs) | Free Cooling Used (tonhrs) | TES Capacity (tonhrs) | TES Temp (F) | Off-Peak Chiller/Aux (kWhr) | Off-Peak Free Cooling (kWhr) | Partial Peak Chiller/Aux (kWhr) | Partial Peak Free Cooling (kWhr) | Total (kWhr) |
|---|---|---|---|---|---|---|---|---|---|---|
| 28-Oct | | | | | | | | | | |
| 29-Oct | | | | | | | | | | |
| 30-Oct | | | | | | | | | | |
| 31-Oct | | | | | | | | | | |
| 1-Nov | 0 | 7920 | 0 | 12574 | 39 | 0 | 0 | 0 | 0 | 0 |
| 2-Nov | 0 | 7920 | 0 | 7670 | 39 | 754 | 0 | 1544 | 0 | 2297 |
| 3-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 4-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 5-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 6-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 7-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 8-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 9-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 10-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 11-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 12-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 13-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 14-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 15-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 16-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 17-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 18-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 19-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 20-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 21-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 22-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 23-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 24-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 25-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 26-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 27-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 28-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 29-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 30-Nov | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 1-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 2-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 3-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 4-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 5-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 6-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 7-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 8-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 9-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 10-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 11-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 12-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 13-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 14-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 15-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 16-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 17-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 18-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 19-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 20-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 21-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 22-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 23-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 24-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 25-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 26-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 27-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 28-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 29-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 30-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 31-Dec | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 1-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 2-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 3-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 4-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 5-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 6-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 7-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 8-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 9-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 10-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 11-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 12-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 13-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 14-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 15-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 16-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 17-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 18-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 19-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |

## Table 2. Daily Winter Cooling Profiles and Energy Consumption

*Assumptions:*

| | | | |
|---|---|---|---|
| **Free Cooling Mode =** | no | Primary CW Pumps Running = | 1 |
| Off-Peak TES Charging Only = | no | Cooling Tower Pumps Running = | 1 |
| Off & Partial Peak TES Charging = | yes | Cooling Tower Fans Running = | 1 |
| Max WBT for Free Cooling = | 45 | Chillers Running = | 1 |

| Day | Free Cooling Availability (tonhrs) | Campus Cooling Load (tonhrs) | Free Cooling Used (tonhrs) | TES Capacity (tonhrs) | TES Temp (F) | Off-Peak Chiller/Aux (kWhr) | Off-Peak Free Cooling (kWhr) | Partial Peak Chiller/Aux (kWhr) | Partial Peak Free Cooling (kWhr) | Total (kWhr) |
|---|---|---|---|---|---|---|---|---|---|---|
| 20-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 21-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 22-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 23-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 24-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 25-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 26-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 27-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 28-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 29-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 30-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 31-Jan | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 1-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 2-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 3-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 4-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 5-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 6-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 7-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 8-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 9-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 10-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 11-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 12-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 13-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 14-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 15-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 16-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 17-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 18-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 19-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 20-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 21-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 22-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 23-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 24-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 25-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 26-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 27-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 28-Feb | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 1-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 2-Mar | 0 | 8311 | 0 | 7670 | 39 | 2512 | 0 | 3815 | 0 | 6326 |
| 3-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 4-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 5-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 6-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 7-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 8-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 9-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 10-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 11-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 12-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 13-Mar | 0 | 8507 | 0 | 7670 | 39 | 2512 | 0 | 3963 | 0 | 6475 |
| 14-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 15-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 16-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 17-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 18-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 19-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 20-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 21-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 22-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 23-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 24-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 25-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 26-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 27-Mar | 0 | 7920 | 0 | 7670 | 39 | 2512 | 0 | 3517 | 0 | 6029 |
| 28-Mar | | | | | | | | | | 0 |
| 29-Mar | | | | | | | | | | |
| 30-Mar | | | | | | | | | | |
| 31-Mar | | | | | | | | | | |
| 1-Apr | | | | | | | | | | |
| 2-Apr | | | | | | | | | | |
| 3-Apr | | | | | | | | | | |
| 4-Apr | | | | | | | | | | |
| 5-Apr | | | | | | | | | | |
| 6-Apr | | | | | | | | | | |
| 7-Apr | | | | | | | | | | |
| 8-Apr | | | | | | | | | | |
| Total | 0 | 1,165,218 | 0 | 1,132,451 | | 364,980 | 0 | 512,205 | 0 | 877,185 |

# Table 2. Daily Winter Cooling Profiles and Energy Consumption

*Assumptions:*

| | | | |
|---|---|---|---|
| **Free Cooling Mode =** | no | Primary CW Pumps Running = | 1 |
| Off-Peak TES Charging Only = | no | Cooling Tower Pumps Running = | 1 |
| Off & Partial Peak TES Charging = | yes | Cooling Tower Fans Running = | 1 |
| Max WBT for Free Cooling = | 45 | Chillers Running = | 1 |

| Day | Free Cooling Availability (tonhrs) | Campus Cooling Load (tonhrs) | Free Cooling Used (tonhrs) | TES Capacity (tonhrs) | TES Temp (F) | Off-Peak Chiller/Aux (kWhr) | Off-Peak Free Cooling (kWhr) | Partial Peak Chiller/Aux (kWhr) | Partial Peak Free Cooling (kWhr) | Total (kWhr) |
|---|---|---|---|---|---|---|---|---|---|---|
| MONTHLY TOTALS | | | | | | | | | | |
| Nov | 0 | 237,600 | 0 | 235,015 | 39 | 71,087 | 0 | 100,010 | 0 | 171,097 |
| Dec | 0 | 245,520 | 0 | 237,782 | 39 | 77,869 | 0 | 109,017 | 0 | 186,886 |
| Jan | 0 | 245,520 | 0 | 237,782 | 39 | 77,869 | 0 | 109,017 | 0 | 186,886 |
| Feb | 0 | 221,760 | 0 | 214,771 | 39 | 70,333 | 0 | 98,467 | 0 | 168,800 |
| Mar | 0 | 214,818 | 0 | 207,101 | 39 | 67,821 | 0 | 95,695 | 0 | 163,516 |
| Total | 0 | 1,165,218 | 0 | 1,132,451 | 39 | 364,980 | 0 | 512,205 | 0 | 877,185 |

**Install Variable Frequency Drives on Chillers (Site 2410)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | Variable Frequency Drives |
| Site Description | Office |

**Measure Description** Install Variable Frequency Drives (VFD's) on a 350-ton and a 200-ton chiller to optimize part load performance.

**Summary of Ex Ante Impact Calculations** Impacts were developed by a PG&E representative using a temperature bin model incorporating pre- and post-retrofit chiller efficiencies at various operating points.

**Comments on PG&E Calculations** The correct climate zone and chiller characteristics were used in the application.

**Evaluation Process** The evaluation process consisted of reviewing the application form and supporting documentation. The contact requested that the on-site be coordinated with their account representative. Several attempts were unsuccessful to contact the representative therefore a thorough review of the application was conducted. Ex ante impact estimates are accepted as accurate.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 65 | 530,960.27 | 0 |
| **Adjusted Engineering** | 65 | 530,960.27 | 0 |
| **Engineering Realization Rate** | 1.00 | 1.00 | N/A |

**Chiller Replacement (Site 2413)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | High Efficiency Water-Cooled Chiller |
| Site Description | Office |

**Measure Description** Replace two existing chillers with high-efficiency water-cooled chillers.

**Summary of Ex Ante Impact Calculations** Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and chiller characteristics.

**Comments on PG&E Calculations** The correct climate zone, chiller size category and building characteristics were used in the application calculations. However, the calibration to customer billing records appears to have vastly over-estimated the chiller contribution to those bills, resulting in a considerable over-estimation of impact. The most likely sources of error are in the hours of operation for the chillers.

**Evaluation Process** The evaluation process consists of a review of the application form and supporting documentation, conducting an on-site survey and then computing impacts using the on-site data.

The on-site survey was conducted on September 15, 1999 in San Mateo (Climate Zone 3). Information on the retrofit equipment and operating conditions were collected through an inspection of the chiller and through an interview with the Chief Engineer. The site consists of two independent buildings, with one chiller in each building.

Discussions provided data for development of a relationship between chiller loading and outdoor dry bulb. The chillers are available from 7:00 am to 6:00 pm on weekdays only. Cooling is available for after-hours and weekends in 2 hour increments. The Chillers are generally brought on line at 60 degrees outside air temperature. The Chief Engineer estimated that the chillers reach 70% loading at approximately 100 degrees outside air temperature.

Models are calibrated with actual weather, observed chiller run hours since the installation, the chiller lock-out temperature, chiller loading under outdoor temperature conditions, chilled water temperature, and condenser water temperature. Energy impacts are based on typical weather data. A Title 24 baseline, nominal efficiency, and typical year bin weather data for the applicable climate zone are used in the bin analysis. To compute the impacts, the following assumptions were used:

- A linear loading strategy was used for the analysis of both the baseline and rebated chillers, which assumed initial loading at 60 degrees F and 70% loading at 100 Degrees F.

- For the baseline chiller case a Title 24 baseline efficiency of 0.748KW/ton was used, based on a water-cooled chiller greater than 300 tons.

Chiller efficiencies at various temperatures were calculated from updated default performance coefficients provided in a memo to the California Energy Commission titled "1995 Proposed Changes to the ACM Manual Central Plant Cooling Equipment" by Mark Hydeman. These coefficients were used to develop a chiller efficiency curve for the Rebate case and a Title 24 base case. The efficiencies for the new chillers were adjusted to account for the variable speed drives installed on the motors by utilizing chiller performance curves for both chillers with and without VSD's at ARI rating conditions. Evaluation-based energy impacts were lower than Ex Ante estimates, and demand impacts were higher. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 62 | 559,083.43 | 0 |
| **Adjusted Engineering** | 98.56 | 76,911.17 | 0 |
| **Engineering Realization Rate** | 1.59 | 0.14 | N/A |

Site 2413: Overall Results

| Bldg 155 | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 197,019.00 | 36.00 | | |
| QC | 34,184.86 | 44.02 | 56,336.52 | 53.08 |
| Realization Rate | 0.17 | 1.22 | | |

| Bldg 177 | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 361,962.00 | 33.00 | | |
| QC | 42,726.31 | 54.54 | 80,231.10 | 126.66 |
| Realization Rate | 0.12 | 1.65 | | |

| Total | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 559,083.00 | 62.00 | | |
| QC | 76,911.17 | 98.56 | 136,567.62 | 179.73 |
| Realization Rate | 0.14 | 1.59 | | |

Site 2413: Results, Bldg 177

| Post-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.593 |
| Nom. Tons | 300 |
| nom kw | 177.9 |

| | Energy | | Demand | |
|---|---|---|---|---|
| | Savings | Impact | Savings | Impact |
| MDSS | | 361,962 | | 33 |
| QC | 80,231 | 42,726 | 127 | 55 |
| Realization Rate | | 0.12 | | 1.65 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 102 | 0.00 | 210 | 0.32 | 0.00 | 0.00 | 1.00 | 66.29 |
| 97 | 0.00 | 187 | 0.31 | 0.00 | 0.00 | 6.00 | 343.83 |
| 92 | 0.71 | 163 | 0.30 | 34.92 | 48.89 | 20.00 | 977.74 |
| 87 | 20.00 | 140 | 0.30 | 828.94 | 41.45 | 49.00 | 2,030.90 |
| 82 | 41.43 | 117 | 0.31 | 1,497.19 | 36.14 | 90.00 | 3,252.51 |
| 77 | 125.00 | 93 | 0.33 | 3,811.23 | 30.49 | 187.00 | 5,701.61 |
| 72 | 283.57 | 70 | 0.34 | 6,824.39 | 24.07 | 306.00 | 7,364.15 |
| 67 | 490.71 | 47 | 0.40 | 9,172.93 | 18.69 | 439.00 | 8,206.24 |
| 62 | 679.29 | 23 | 0.60 | 9,499.94 | 13.99 | 306.00 | 4,279.47 |
| Totals | 1,640.71 | | | 31,669.54 | 48.89 | 1,404.00 | 32,222.74 |

| Title 24 Baseline Chiller | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 300 |
| nom kw | 224.400 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 102 | 0.00 | 300 | 0.44 | 0.00 | 0.00 |
| 97 | 0.00 | 267 | 0.44 | 0.00 | 0.00 |
| 92 | 0.71 | 233 | 0.44 | 73.88 | 103.43 |
| 87 | 20.00 | 200 | 0.45 | 1,819.66 | 90.98 |
| 82 | 41.43 | 167 | 0.47 | 3,244.76 | 78.32 |
| 77 | 125.00 | 133 | 0.50 | 8,344.43 | 66.76 |
| 72 | 283.57 | 100 | 0.55 | 15,658.72 | 55.22 |
| 67 | 490.71 | 67 | 0.67 | 21,915.74 | 44.66 |
| 62 | 679.29 | 33 | 1.03 | 23,338.68 | 34.36 |
| Totals | 1,640.71 | | | 74,395.85 | 103.43 |

| Pre-Retrofit Chiller | |
|---|---|
| Nom. Eff | 1 |
| Nom. Tons | 300 |
| nom kw | 300 |

| Outdoor DB Temperature (F) | Operating Hours per year (Actual) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 102 | 1.00 | 300 | 0.59 | 175.54 | 175.54 |
| 97 | 6.00 | 267 | 0.59 | 939.37 | 156.56 |
| 92 | 20.00 | 233 | 0.59 | 2,765.53 | 138.28 |
| 87 | 49.00 | 200 | 0.61 | 5,960.11 | 121.63 |
| 82 | 90.00 | 167 | 0.63 | 9,423.73 | 104.71 |
| 77 | 187.00 | 133 | 0.67 | 16,688.86 | 89.25 |
| 72 | 306.00 | 100 | 0.74 | 22,589.87 | 73.82 |
| 67 | 439.00 | 67 | 0.90 | 26,211.40 | 59.71 |
| 62 | 591.00 | 33 | 1.38 | 27,146.23 | 45.93 |
| Totals | 1689.00 | | | 111,900.65 | 175.54 |

Site 2413: Inputs to Model, Bldg 177

| Parameter | Value Reported | Units of Parameter | Notes |
|---|---|---|---|
| City | San Mateo | | |
| Climate Zone | 3 | | |
| Pre-Retrofit Chiller | | | |
| Nominal Chiller Capacity | 300 | Tons | Application |
| Nominal Chiller Efficiency | 1 | kW/ton | DOE Calibration Run |
| | | | |
| Post-Retrofit Chiller | | | |
| Nominal Chiller Capacity | 300 | Tons | Application |
| Nominal Chiller Efficiency | 0.593 | kW/ton | From Chiller Rating Sheet |
| Full Load Amps | 243 | FLA | From Chiller Display |
| Max kW | 177.9 | kW | Calculated |
| Title 24 Nominal Chiller Efficiency | 0.748 | kW/ton | DOE Baseline Run |
| | | | |
| Setpoints and Scheduling | | | |
| Chiller AM Lockout | 7:00 | AM | M-F; Contact provided schedule; After hours and weekend cooling available in 2 hour increments by request |
| Chiller PM Lockout | 18:00 | PM | |
| Chiller Startup OSA Temperature | 60 | F | Contact provided estimate |
| Chiller Max Load OSA Temperature | ?? | F | Contact provided estimate |
| Chilled Water Supply Temperature Setpoint | 50.6 | F | Contact provided setpoints; Chiller is on Manual Operation |
| Condenser Water Temperature | 65 | F | Contact provided setpoints; Chiller is on Manual Operation |
| Date of Chiller Installation | 2/28/98 | | Application |
| Date at Run Hour Reading | 9/15/99 | | Chiller Log |
| Number of Days Chiller Operated | 403 | days (M-F Only) | Calculated |
| Run Hours for New Chiller | 2714 | hours | Chiller Log |
| Average Hours per Year of Chiller Operation | 1756.40 | Hours/Year (M-F Only) | Calculated from Observed Operating Conditions |
| | | | |
| Run Hours Since Install Using Actual Weather & Setpoints | 2841.00 | hours | Based on schedule and setpoints provided in interview and actual weather data |
| Hours per Year from Actual Weather Data | 1098.00 | Hours/Year (M-F Only) | Based on schedule and setpoints provided in interview and actual weather data |

Site 2413: Post-Retrofit Chiller, Bldg 177

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

Post-Retrofit Chiller

| | |
|---|---|
| Nom. Eff | 0.593 |
| Nom. Tons | 300 |
| nom kw | 177.9 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | | VSD Correction | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton | Scaling Ratio | Corrected kW/ton for VSD |
| 102 | 210 | 65 | 57 | 269 | 0.700 | 0.70 | 0.59 | 0.0989 | 10.11 | 0.348 | 0.91 | 0.316 |
| 97 | 187 | 64.5 | 56.2 | 272 | 0.622 | 0.63 | 0.59 | 0.1010 | 9.91 | 0.355 | 0.86 | 0.307 |
| 92 | 163 | 64 | 55.4 | 275 | 0.544 | 0.56 | 0.60 | 0.1039 | 9.63 | 0.365 | 0.82 | 0.299 |
| 87 | 140 | 64 | 54.6 | 279 | 0.467 | 0.50 | 0.61 | 0.1090 | 9.18 | 0.383 | 0.77 | 0.296 |
| 82 | 117 | 63.5 | 53.8 | 282 | 0.389 | 0.44 | 0.61 | 0.1155 | 8.66 | 0.406 | 0.76 | 0.310 |
| 77 | 93 | 63.5 | 53 | 285 | 0.311 | 0.38 | 0.62 | 0.1269 | 7.88 | 0.446 | 0.73 | 0.327 |
| 72 | 70 | 63 | 52.2 | 287 | 0.233 | 0.32 | 0.62 | 0.1452 | 6.89 | 0.511 | 0.67 | 0.344 |
| 67 | 47 | 63 | 51.4 | 291 | 0.156 | 0.27 | 0.63 | 0.1847 | 5.41 | 0.649 | 0.62 | 0.401 |
| 62 | 23 | 62.5 | 50.6 | 292 | 0.078 | 0.22 | 0.64 | 0.3028 | 3.30 | 1.065 | 0.56 | 0.599 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2413: Baseline Chiller, Bldg 177

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

Post-Retrofit Chiller

| | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 300 |
| nom kw | 224.4 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 102 | 300 | 65 | 57 | 269 | 1.000 | 1.00 | 0.59 | 0.1245 | 8.03 | 0.438 |
| 97 | 267 | 64.5 | 56.2 | 272 | 0.889 | 0.88 | 0.59 | 0.1249 | 8.01 | 0.439 |
| 92 | 233 | 64 | 55.4 | 275 | 0.778 | 0.77 | 0.60 | 0.1261 | 7.93 | 0.443 |
| 87 | 200 | 64 | 54.6 | 279 | 0.667 | 0.67 | 0.61 | 0.1294 | 7.73 | 0.455 |
| 82 | 167 | 63.5 | 53.8 | 282 | 0.556 | 0.57 | 0.61 | 0.1337 | 7.48 | 0.470 |
| 77 | 133 | 63.5 | 53 | 285 | 0.444 | 0.48 | 0.62 | 0.1424 | 7.02 | 0.501 |
| 72 | 100 | 63 | 52.2 | 287 | 0.333 | 0.39 | 0.62 | 0.1571 | 6.37 | 0.552 |
| 67 | 67 | 63 | 51.4 | 291 | 0.222 | 0.31 | 0.63 | 0.1905 | 5.25 | 0.670 |
| 62 | 33 | 62.5 | 50.6 | 292 | 0.111 | 0.24 | 0.64 | 0.2932 | 3.41 | 1.031 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2413: Pre-Retrofit Chiller, Bldg 177

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

Post-Retrofit Chiller

| | |
|---|---|
| Nom. Eff | 1 |
| Nom. Tons | 300 |
| nom kw | 300 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 102 | 300 | 65 | 57 | 269 | 1.000 | 1.00 | 0.59 | 0.1664 | 6.01 | 0.585 |
| 97 | 267 | 64.5 | 56.2 | 272 | 0.889 | 0.88 | 0.59 | 0.1670 | 5.99 | 0.587 |
| 92 | 233 | 64 | 55.4 | 275 | 0.778 | 0.77 | 0.60 | 0.1685 | 5.93 | 0.593 |
| 87 | 200 | 64 | 54.6 | 279 | 0.667 | 0.67 | 0.61 | 0.1730 | 5.78 | 0.608 |
| 82 | 167 | 63.5 | 53.8 | 282 | 0.556 | 0.57 | 0.61 | 0.1787 | 5.60 | 0.628 |
| 77 | 133 | 63.5 | 53 | 285 | 0.444 | 0.48 | 0.62 | 0.1904 | 5.25 | 0.669 |
| 72 | 100 | 63 | 52.2 | 287 | 0.333 | 0.39 | 0.62 | 0.2100 | 4.76 | 0.738 |
| 67 | 67 | 63 | 51.4 | 291 | 0.222 | 0.31 | 0.63 | 0.2547 | 3.93 | 0.896 |
| 62 | 33 | 62.5 | 50.6 | 292 | 0.111 | 0.24 | 0.64 | 0.3919 | 2.55 | 1.378 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2413: Results, Bldg 155

| | Energy | | Demand | |
|---|---|---|---|---|
| | Savings | Impact | Savings | Impact |
| MDSS | | 197,019 | | 36 |
| QC | 56,337 | 34,185 | 53 | 44 |
| Realization Rate | | 0.17 | | 1.22 |

| Post-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.613 |
| Nom. Tons | 350 |
| nom kw | 214.55 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 102 | 0.00 | 245 | 0.30 | 0.00 | 86.32 | 1.00 | 72.32 |
| 97 | 0.00 | 219 | 0.29 | 0.00 | 79.06 | 6.00 | 378.54 |
| 92 | 0.71 | 193 | 0.28 | 38.91 | 71.90 | 20.00 | 1,089.42 |
| 87 | 20.00 | 166 | 0.28 | 929.58 | 64.85 | 49.00 | 2,277.47 |
| 82 | 41.43 | 140 | 0.29 | 1,670.82 | 57.94 | 90.00 | 3,629.72 |
| 77 | 125.00 | 114 | 0.30 | 4,302.41 | 51.17 | 187.00 | 6,436.41 |
| 72 | 283.57 | 88 | 0.32 | 7,989.63 | 44.56 | 306.00 | 8,621.56 |
| 67 | 490.71 | 61 | 0.37 | 11,034.78 | 38.12 | 439.00 | 9,871.87 |
| 62 | 679.29 | 35 | 0.49 | 11,747.35 | 31.88 | 306.00 | 5,291.86 |
| Totals | 1,640.71 | | | 37,713.49 | 86.32 | 1,404.00 | 37,669.18 |

| Title 24 Baseline Chiller | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 350 |
| nom kw | 261.800 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 102 | 0.00 | 245 | 0.53 | 0.00 | 130.34 |
| 97 | 0.00 | 219 | 0.53 | 0.00 | 115.90 |
| 92 | 0.71 | 193 | 0.53 | 73.12 | 102.37 |
| 87 | 20.00 | 166 | 0.54 | 1,807.90 | 90.39 |
| 82 | 41.43 | 140 | 0.56 | 3,251.01 | 78.47 |
| 77 | 125.00 | 114 | 0.59 | 8,356.80 | 66.85 |
| 72 | 283.57 | 88 | 0.65 | 16,173.67 | 57.04 |
| 67 | 490.71 | 61 | 0.77 | 23,289.62 | 47.46 |
| 62 | 679.29 | 35 | 1.10 | 18,946.23 | 38.61 |
| Totals | 1,640.71 | | | 71,898.35 | 130.34 |

| Pre-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.8 |
| Nom. Tons | 350 |
| nom kw | 280 |

| Outdoor DB Temperature (F) | Operating Hours per year (Actual) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 102 | 1.00 | 245 | 0.57 | 139.40 | 139.40 |
| 97 | 6.00 | 219 | 0.57 | 744.49 | 124.08 |
| 92 | 20.00 | 193 | 0.57 | 2,193.96 | 109.70 |
| 87 | 49.00 | 166 | 0.58 | 4,714.66 | 96.22 |
| 82 | 90.00 | 140 | 0.60 | 7,524.80 | 83.61 |
| 77 | 187.00 | 114 | 0.63 | 13,434.37 | 71.84 |
| 72 | 306.00 | 88 | 0.70 | 18,631.05 | 60.89 |
| 67 | 439.00 | 61 | 0.83 | 22,262.79 | 50.71 |
| 62 | 591.00 | 35 | 1.18 | 24,404.50 | 41.29 |
| Totals | 1689.00 | | | 94,050.01 | 139.40 |

Site 2413: Inputs to Model, Bldg 155

| Parameter | Value Reported | Units of Parameter | Notes |
|---|---|---|---|
| City | San Mateo | | |
| Climate Zone | 3 | | |
| Pre-Retrofit Chiller | | | |
| Nominal Chiller Capacity | 350 | Tons | Application |
| Nominal Chiller Efficiency | 0.8 | kW/ton | DOE Calibration Run |
| | | | |
| Post-Retrofit Chiller | | | |
| Nominal Chiller Capacity | 350 | Tons | Application |
| Nominal Chiller Efficiency | 0.613 | kW/ton | From Chiller Rating Sheet |
| Full Load Amps | 296 | FLA | From Chiller Display |
| Max kW | 214.55 | kW | Calculated |
| Title 24 Nominal Chiller Efficiency | 0.748 | kW/ton | DOE Baseline Run |
| | | | |
| Setpoints and Scheduling | | | |
| Chiller AM Lockout | 7:00 | AM | M-F; Contact provided schedule; After hours and weekend cooling available in 2 hour increments by request |
| Chiller PM Lockout | 18:00 | PM | |
| Chiller Startup OSA Temperature | 60 | F | Contact provided estimate |
| Chiller Max Load OSA Temperature | ?? | F | Contact provided estimate |
| Chilled Water Supply Temperature Setpoint | 50.6 | F | Contact provided setpoints; Chiller is on Manual Operation |
| Condenser Water Temperature | 65 | F | Contact provided setpoints; Chiller is on Manual Operation |
| Date of Chiller Installation | 2/28/98 | | Application |
| Date at Run Hour Reading | 9/15/99 | | Chiller Log |
| Number of Days Chiller Operated | 403 | days (M-F Only) | Calculated |
| Run Hours for New Chiller | 2714 | hours | Chiller Log |
| Average Hours per Year of Chiller Operation | 1756.40 | Hours/Year (M-F Only) | Calculated from Observed Operating Conditions |
| | | | |
| Run Hours Since Install Using Actual Weather & Setpoints | 2841.00 | hours | Based on schedule and setpoints provided in interview and actual weather data |
| Hours per Year from Actual Weather Data | 1098.00 | Hours/Year (M-F Only) | Based on schedule and setpoints provided in interview and actual weather data |

Site 2413: Post-Retrofit Chiller, Bldg 155

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

Post-Retrofit Chiller

| | |
|---|---|
| Nom. Eff | 0.613 |
| Nom. Tons | 350 |
| nom kw | 214.55 |

| | Current Data | | | Calculated Values | | | | Efficiency | | | VSD Correction | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton | Scaling Ratio | Corrected kW/ton for VSD |
| 102 | 245 | 65 | 58 | 306 | 0.700 | 0.70 | 0.58 | 0.1002 | 9.98 | 0.352 | 0.84 | 0.295 |
| 97 | 219 | 64.6875 | 57.075 | 312 | 0.625 | 0.63 | 0.58 | 0.1028 | 9.73 | 0.361 | 0.80 | 0.288 |
| 92 | 193 | 64.375 | 56.15 | 317 | 0.550 | 0.57 | 0.59 | 0.1062 | 9.41 | 0.373 | 0.76 | 0.283 |
| 87 | 166 | 64.0625 | 55.225 | 322 | 0.475 | 0.50 | 0.60 | 0.1109 | 9.01 | 0.390 | 0.72 | 0.280 |
| 82 | 140 | 63.75 | 54.3 | 327 | 0.400 | 0.44 | 0.61 | 0.1177 | 8.50 | 0.414 | 0.70 | 0.288 |
| 77 | 114 | 63.4375 | 53.375 | 331 | 0.325 | 0.39 | 0.62 | 0.1279 | 7.82 | 0.450 | 0.67 | 0.303 |
| 72 | 88 | 63.125 | 52.45 | 335 | 0.250 | 0.33 | 0.62 | 0.1448 | 6.90 | 0.509 | 0.63 | 0.322 |
| 67 | 61 | 62.8125 | 51.525 | 338 | 0.175 | 0.28 | 0.63 | 0.1770 | 5.65 | 0.622 | 0.59 | 0.367 |
| 62 | 35 | 62.5 | 50.6 | 341 | 0.100 | 0.23 | 0.64 | 0.2590 | 3.86 | 0.911 | 0.54 | 0.494 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2413: Baseline Chiller, Bldg 155

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

Post-Retrofit Chiller

| | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 350 |
| nom kw | 261.8 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 102 | 245 | 77.5 | 57 | 344 | 0.700 | 0.70 | 0.71 | 0.1513 | 6.61 | 0.532 |
| 97 | 219 | 75.5 | 56.2 | 345 | 0.625 | 0.63 | 0.70 | 0.1507 | 6.64 | 0.530 |
| 92 | 193 | 73.5 | 55.4 | 346 | 0.550 | 0.57 | 0.69 | 0.1513 | 6.61 | 0.532 |
| 87 | 166 | 72 | 54.6 | 347 | 0.475 | 0.50 | 0.68 | 0.1546 | 6.47 | 0.544 |
| 82 | 140 | 70 | 53.8 | 346 | 0.400 | 0.44 | 0.67 | 0.1594 | 6.27 | 0.561 |
| 77 | 114 | 67.5 | 53 | 344 | 0.325 | 0.39 | 0.66 | 0.1672 | 5.98 | 0.588 |
| 72 | 88 | 66 | 52.2 | 344 | 0.250 | 0.33 | 0.65 | 0.1854 | 5.39 | 0.652 |
| 67 | 61 | 64 | 51.4 | 342 | 0.175 | 0.28 | 0.64 | 0.2204 | 4.54 | 0.775 |
| 62 | 35 | 62 | 50.6 | 339 | 0.100 | 0.23 | 0.63 | 0.3137 | 3.19 | 1.103 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2413: Pre-Retrofit Chiller, Bldg 155

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

Post-Retrofit Chiller

| | |
|---|---|
| Nom. Eff | 0.8 |
| Nom. Tons | 350 |
| nom kw | 280 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 102 | 245 | 77.5 | 57 | 344 | 0.700 | 0.70 | 0.71 | 0.1618 | 6.18 | 0.569 |
| 97 | 219 | 75.6 | 56.2 | 345 | 0.625 | 0.63 | 0.70 | 0.1613 | 6.20 | 0.567 |
| 92 | 193 | 73.6 | 55.4 | 346 | 0.550 | 0.57 | 0.69 | 0.1621 | 6.17 | 0.570 |
| 87 | 166 | 71.7 | 54.6 | 346 | 0.475 | 0.50 | 0.68 | 0.1646 | 6.08 | 0.579 |
| 82 | 140 | 69.8 | 53.8 | 346 | 0.400 | 0.44 | 0.67 | 0.1699 | 5.89 | 0.597 |
| 77 | 114 | 67.8 | 53.0 | 345 | 0.325 | 0.39 | 0.66 | 0.1796 | 5.57 | 0.632 |
| 72 | 88 | 65.9 | 52.2 | 344 | 0.250 | 0.33 | 0.65 | 0.1979 | 5.05 | 0.696 |
| 67 | 61 | 63.9 | 51.4 | 342 | 0.175 | 0.28 | 0.64 | 0.2355 | 4.25 | 0.828 |
| 62 | 35 | 62 | 50.6 | 339 | 0.100 | 0.23 | 0.63 | 0.3356 | 2.98 | 1.180 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2413: Weather Data for Both Buildings

TMY temperature data

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 0 | 0 | 1 | 4 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 37 | 6 | 9 | 13 | 13 | 16 | 15 | 18 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 6 | |
| 42 | 28 | 31 | 34 | 46 | 45 | 44 | 38 | 28 | 12 | 5 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 5 | 6 | 7 | 16 | 21 | 26 | |
| 47 | 72 | 77 | 79 | 84 | 71 | 66 | 70 | 65 | 43 | 31 | 12 | 8 | 6 | 3 | 2 | 2 | 2 | 6 | 21 | 32 | 44 | 43 | 48 | 54 | |
| 52 | 120 | 125 | 125 | 116 | 127 | 122 | 104 | 85 | 79 | 68 | 60 | 43 | 26 | 20 | 17 | 21 | 36 | 53 | 68 | 78 | 93 | 107 | 124 | 127 | |
| 57 | 116 | 105 | 100 | 90 | 95 | 106 | 112 | 120 | 104 | 89 | 83 | 79 | 68 | 70 | 80 | 79 | 95 | 108 | 115 | 129 | 129 | 137 | 127 | 125 | |
| 62 | 21 | 17 | 12 | 11 | 9 | 11 | 19 | 58 | 98 | 102 | 91 | 77 | 77 | 83 | 79 | 84 | 91 | 111 | 109 | 99 | 83 | 55 | 35 | 25 | 679.2857 |
| 67 | 2 | 0 | 1 | 1 | 1 | 1 | 3 | 5 | 20 | 56 | 74 | 77 | 72 | 78 | 84 | 78 | 83 | 60 | 38 | 19 | 9 | 4 | 5 | 2 | 490.7143 |
| 72 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 9 | 32 | 51 | 64 | 61 | 58 | 57 | 37 | 19 | 9 | 2 | 0 | 0 | 0 | 0 | 283.5714 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 10 | 21 | 31 | 30 | 28 | 28 | 15 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 125 |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 8 | 13 | 11 | 11 | 9 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 41.42857 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 7 | 5 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.714286 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 102 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| On Hours | | | | | | | | 46.4 | 90 | 122.9 | 149.3 | 167.9 | 189.3 | 193.6 | 189.3 | 187.1 | 165 | 140 | | | | | | | **961.43** |

Note: Total "On Hours" value has been scaled by 5/7 to account for M-F operation only

Actual temperature data by climate zone for 7/20/98 to 7/19/99, M-F only

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | . | . | . | .. | . | . | . | . | . | . | . | . | . | 1 | 2 | 3 | |
| 37 | 2 | 3 | 5 | 5 | 7 | 8 | 8 | 3 | 5 | 1 | . | . | . | . | . | . | . | 1 | 1 | 3 | 3 | 3 | 2 | 2 | |
| 42 | 26 | 26 | 29 | 36 | 35 | 36 | 27 | 23 | 7 | 5 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 2 | 6 | 5 | 9 | 13 | 18 | 20 | |
| 47 | 43 | 45 | 48 | 44 | 45 | 39 | 35 | 30 | 28 | 21 | 13 | 6 | 6 | 5 | 5 | 6 | 9 | 11 | 18 | 33 | 37 | 39 | 42 | 45 | |
| 52 | 72 | 74 | 72 | 68 | 74 | 67 | 63 | 49 | 42 | 34 | 33 | 29 | 23 | 19 | 19 | 22 | 33 | 58 | 72 | 73 | 73 | 74 | 70 | 69 | |
| 57 | 71 | 70 | 67 | 70 | 67 | 66 | 60 | 54 | 51 | 54 | 56 | 48 | 47 | 52 | 56 | 62 | 68 | 70 | 68 | 68 | 64 | 61 | 65 | 66 | |
| 62 | 33 | 32 | 30 | 28 | 24 | 36 | 41 | 59 | 62 | 55 | 44 | 53 | 54 | 50 | 57 | 56 | 53 | 48 | 43 | 38 | 46 | 48 | 46 | 43 | 591 |
| 67 | 7 | 5 | 5 | 5 | 4 | 4 | 18 | 25 | 40 | 49 | 54 | 43 | 37 | 40 | 38 | 44 | 41 | 28 | 26 | 28 | 21 | 16 | 14 | 11 | 439 |
| 72 | 3 | 2 | . | . | . | . | 4 | 11 | 17 | 27 | 32 | 41 | 44 | 40 | 34 | 24 | 19 | 17 | 16 | 9 | 6 | 6 | 1 | 2 | 306 |
| 77 | . | . | . | . | . | . | . | 2 | 6 | 10 | 15 | 22 | 27 | 25 | 23 | 23 | 19 | 15 | 7 | 3 | 2 | . | 1 | . | 187 |
| 82 | . | . | . | . | . | . | . | . | 3 | 5 | 8 | 7 | 12 | 16 | 14 | 9 | 9 | 7 | 1 | 1 | . | . | . | . | 90 |
| 87 | . | . | . | . | . | . | . | . | . | . | 3 | 9 | 6 | 9 | 6 | 8 | 6 | 2 | 3 | . | . | . | . | . | 49 |
| 92 | . | . | . | . | . | . | . | . | . | . | . | . | 4 | 3 | 6 | 4 | 2 | 1 | . | . | . | . | . | . | 20 |
| 97 | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 2 | 1 | 1 | 1 | . | . | . | . | . | . | 6 |
| 102 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | 1 |
| On Hours | . | | | | | | | 97 | 128 | 146 | 156 | 175 | 184 | 184 | 180 | 170 | 150 | 119 | | | | | | | **1098** |

**EMS System Upgrade (Site 2437)**

| | |
|---|---|
| Program | Advance Performance Options |
| Measure | Customized Controls |
| Site Description | Office |

**Measure Description**

Install time-of-day controls on the water loop heat pumps serving the first floors of each of three buildings. This will reduce the operating hours of the heat pumps from nearly continuous operation to operating only during set hours.

**Summary of Ex Ante Impact Calculations**

Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and HVAC system characteristics.

**Comments on Calculations**

Impact calculations were based on the reduction of operating hours. The baseline model was the pre-retrofit building, which had recently installed other energy efficiency measures that the impacts are dependent upon. Equipment efficiencies, size, quantity, and operating characteristics were not supplied in adequate detail to evaluate the measure.

**Evaluation Process**

The evaluation process consisted of reviewing the application form and supporting documentation and conducting an on-site survey.

The on-site survey was conducted on September 21, 1999 in Walnut Creek (Climate Zone 12) with the Chief Engineer. Pre- and post-retrofit schedules were reconfirmed through interviews with the Chief Engineer. Visual inspection was not feasible due to multiple tenants in the building, so a list of quantities and model numbers for heat pumps on the first floor was obtained from the Chief Engineer's records. Upon further review, the list was for the incorrect building. The correct list was not available, and due to the disruptive nature of an on-site inspection, the heat pumps were not visually inspected.

The engineering calculations used for the analyses were accepted as an accurate representation of pre- and post-retrofit conditions and were adopted as the evaluation-based impact estimates.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 0.0 | 147,060.94 | 1,137 |
| **Adjusted Engineering** | 0.0 | 147,060.94 | 1,137 |
| **Engineering Realization Rate** | N/A | 1.0 | 1.0 |

EMS System Upgrade (Site 2448)

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | Energy Management System |
| Site Description | Health Care/Hospital |

**Measure Description** Install an Energy Management System (EMS) to control all HVAC equipment.

**Summary of Ex Ante Impact Calculations** Impacts were developed using DOE2.1E simulation program based on climate zone, building type, HVAC equipment, and scheduling characteristics.

**Comments on PG&E Calculations** The application calculations are dependent upon several other energy conservation measures being implemented including a lighting retrofit, connection of humidifiers, change in rate structure, and reduction of outside air to original design values.

**Evaluation Process** The evaluation process consists of a review of the application form and supporting documentation. The hospital is located in San Rafael (Climate Zone 2). A telephone interview with a Building Engineer was conducted on November 11, 1999. The contact stated that the scheduling for the EMS has not yet been implemented and the HVAC system is currently operating 24 hours per day, 7 days per week. Although the scheduling is to be implemented in the future, there are no current energy or demand impacts due to the retrofit.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 66 | 355,177.07 | 79,821 |
| **Adjusted Engineering** | 0 | 0 | 0 |
| **Engineering Realization Rate** | 0.00 | 0.00 | 0.00 |

**Chiller & Cooling Tower Replacement (Site 2462)**

| | |
|---|---|
| Program | Retrofit Efficiency Options Program |
| Measure | High Efficiency Water-Cooled Chiller and Oversized Cooling Tower |
| Site Description | School |

**Measure Description**

Replace existing water-cooled chiller with a 500-ton high-efficiency water-cooled chiller and replace cooling tower with an oversized cooling tower.

**Summary of Ex Ante Impact Calculations**

Tables of standard values were developed using the HBSSM simulation program based on climate zone, chiller size, building type, chiller efficiency, condenser water temperature, wet-bulb temperature, and cooling tower approach temperature. Values from these tables are used to calculate the rebate and associated impacts.

**Comments on PG&E Calculations**

The application calculations used the correct climate zone, chiller size, cooling tower fan horsepower, and building characteristics.

**Evaluation Process**

The evaluation process consists of a review of the application form and supporting documentation, conducting an on-site survey and then computing impacts using the on-site data.

The on-site survey was conducted on August 10, 1999 in Lemoore (Climate Zone 13). Information on the retrofit equipment and operating conditions was collected through an inspection of the chiller and cooling tower and through an interview with the Plant Engineer.

Discussions provided data for development of a relationship between chiller loading and outdoor dry bulb. The chiller is available from 7:00 am to 6:00 pm, Monday through Friday, including summer. The chiller is brought on line at 60 degrees outside air temperature. The contact stated that the chiller is fully loaded at approximately 112 degrees F.

Models are calibrated with actual weather, observed chiller run hours since the installation, chiller loading under extreme outdoor temperature conditions, chilled water temperature, and condenser water temperature. Energy impacts are based on typical weather data. A Title 24 baseline, nominal efficiency, and typical year bin weather data for the applicable climate zone are used in the bin analysis. To compute the impacts, the following assumptions were used:

- A linear loading strategy was used for the analysis of both the baseline and rebated chillers, which assumed initial loading at 60 degrees F and 100% loading at 112 degrees F.
- Based on a water-cooled screw chiller greater than 300 tons, a baseline Title 24 efficiency of 0.748 KW/ton was used.
- The post-retrofit cooling tower approach temperature was 5.7

degrees F.

- The baseline for the cooling tower retrofit was assumed to be the post-retrofit chiller with a 10-degree F approach temperature.

- The new cooling tower provides energy savings of 0.01 kW/ton for each degree F decrease in approach temperature.

Chiller efficiencies at various temperatures were calculated from updated default performance coefficients provided in a memo to the California Energy Commission titled "1995 Proposed Changes to the ACM Manual Central Plant Cooling Equipment" by Mark Hydeman. These coefficients were used to develop a chiller efficiency curve for the Rebate case and a Title 24 base case. Evaluation-based energy impacts were lower and demand impacts were higher than Ex Ante estimates. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 82.95 | 240,055.98 | 0 |
| **Adjusted Engineering** | 117.07 | 141,639.15 | 0 |
| **Engineering Realization Rate** | 1.41 | 0.59 | N/A |

Site 2462: Results

| Chiller & CT | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 240,056 | 83.055 | | |
| QC | 141,639 | 117 | -112,629 | 22 |
| Realization Rate | 0.59 | 1.41 | | |

| Pre-Retrofit Chiller | |
|---|---|
| Nom. Eff | 1 |
| Nom. Tons | 150 |
| nom kw | 150 |

| Outdoor DB Temperature (F) | Operating Hours per year (Actual) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 112 | 0.00 | 150 | 0.970 | 0.00 | 145.47 |
| 107 | 34.00 | 138 | 0.960 | 4,493.67 | 132.17 |
| 102 | 96.00 | 124 | 0.952 | 11,346.40 | 118.19 |
| 97 | 176.00 | 110 | 0.950 | 18,471.19 | 104.95 |
| 92 | 254.50 | 97 | 0.955 | 23,523.37 | 92.43 |
| 87 | 261.50 | 83 | 0.969 | 21,081.98 | 80.62 |
| 82 | 315.00 | 70 | 0.999 | 21,894.81 | 69.51 |
| 77 | 323.00 | 56 | 1.057 | 19,083.49 | 59.08 |
| 72 | 285.00 | 42 | 1.167 | 14,059.63 | 49.33 |
| 67 | 344.00 | 29 | 1.405 | 13,844.62 | 40.25 |
| 62 | 394.50 | 15 | 2.121 | 12,550.08 | 31.81 |
| Totals | 2483.50 | | | 160,349.25 | 145.47 |

| Title 24 Baseline Chiller | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 500 |
| nom kw | 374.043 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 112 | 0.00 | 500 | 0.726 | 0.00 | 362.76 |
| 107 | 5.00 | 459 | 0.718 | 1,647.87 | 329.57 |
| 102 | 96.00 | 414 | 0.713 | 28,293.58 | 294.72 |
| 97 | 206.00 | 368 | 0.711 | 53,911.24 | 261.71 |
| 92 | 305.00 | 323 | 0.714 | 70,297.75 | 230.48 |
| 87 | 314.00 | 277 | 0.725 | 63,124.66 | 201.03 |
| 82 | 380.00 | 232 | 0.748 | 65,863.38 | 173.32 |
| 77 | 351.00 | 186 | 0.791 | 51,712.11 | 147.33 |
| 72 | 338.00 | 141 | 0.873 | 41,579.13 | 123.02 |
| 67 | 367.00 | 95 | 1.051 | 36,831.41 | 100.36 |
| 62 | 415.00 | 50 | 1.587 | 32,921.32 | 79.33 |
| Totals | 2,777.00 | | | 446,182.45 | 362.76 |

| Chiller Only | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 159,529 | 66.105 | | |
| QC | 117,548 | 96 | -134,159 | -122 |
| Realization Rate | 0.74 | 1.45 | | |

| Post-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.551 |
| Nom. Tons | 500 |
| nom kw | 275.5 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 112 | 0.00 | 500 | 0.534 | 0.00 | 267.19 | 0.00 | 0.00 |
| 107 | 5.00 | 459 | 0.529 | 1,213.73 | 242.75 | 34.00 | 8,253.37 |
| 102 | 96.00 | 414 | 0.525 | 20,839.56 | 217.08 | 96.00 | 20,839.56 |
| 97 | 206.00 | 368 | 0.524 | 39,708.17 | 192.76 | 176.00 | 33,925.43 |
| 92 | 305.00 | 323 | 0.526 | 51,777.61 | 169.76 | 254.50 | 43,204.60 |
| 87 | 314.00 | 277 | 0.534 | 46,494.29 | 148.07 | 261.50 | 38,720.57 |
| 82 | 380.00 | 232 | 0.551 | 48,511.49 | 127.66 | 315.00 | 40,213.47 |
| 77 | 351.00 | 186 | 0.582 | 38,088.41 | 108.51 | 323.00 | 35,050.02 |
| 72 | 338.00 | 141 | 0.643 | 30,624.99 | 90.61 | 285.00 | 25,822.85 |
| 67 | 367.00 | 95 | 0.774 | 27,128.08 | 73.92 | 344.00 | 25,427.95 |
| 62 | 415.00 | 50 | 1.169 | 24,248.11 | 58.43 | 394.50 | 23,050.31 |
| Totals | 2,777.00 | | | 328,634.44 | 267.19 | 2,483.50 | 294,508.12 |

| Post-Retrofit Chiller w/ Coolong Tower | |
|---|---|
| Nom. Eff | 0.551 |
| Nom. Tons | 500 |
| nom kw | 275.5 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 112 | 0.00 | 500 | 0.491 | 0.00 | 245.69 | 0.00 | 0.00 |
| 107 | 5.00 | 459 | 0.486 | 1,115.03 | 223.01 | 34.00 | 7,582.18 |
| 102 | 96.00 | 414 | 0.482 | 19,132.07 | 199.29 | 96.00 | 19,132.07 |
| 97 | 206.00 | 368 | 0.481 | 36,446.82 | 176.93 | 176.00 | 31,139.03 |
| 92 | 305.00 | 323 | 0.483 | 47,545.05 | 155.89 | 254.50 | 39,672.83 |
| 87 | 314.00 | 277 | 0.491 | 42,750.56 | 136.15 | 261.50 | 35,602.77 |
| 82 | 380.00 | 232 | 0.508 | 44,723.58 | 117.69 | 315.00 | 37,073.49 |
| 77 | 351.00 | 186 | 0.539 | 35,275.62 | 100.50 | 323.00 | 32,461.61 |
| 72 | 338.00 | 141 | 0.600 | 28,577.02 | 84.55 | 285.00 | 24,096.01 |
| 67 | 367.00 | 95 | 0.731 | 25,621.71 | 69.81 | 344.00 | 24,015.99 |
| 62 | 415.00 | 50 | 1.126 | 23,355.86 | 56.28 | 394.50 | 22,202.13 |
| Totals | 2,777.00 | | 0.00 | 304,543.30 | 245.69 | 2,483.50 | 272,978.11 |

Site 2462: Inputs to Model

| Parameter | Value Reported | Units of Parameter | Notes |
|---|---|---|---|
| City | Lemoore | | |
| Climate Zone | 13 | | |
| Pre-Retrofit Nominal Chiller Capacity | 150 | Tons | Application |
| Pre-Retrofit Nominal Chiller Efficiency | 1 | kW/ton | Assumed Value |
| Pre-Retrofit Cooling Tower Approach Temperature | 10 | F | Assumed Value |
| | | | |
| Post-Retrofit Nominal Chiller Capacity | 500 | Tons | Application |
| Post-Retrofit Nominal Chiller Efficiency | 0.551 | kW/ton | From Chiller Rating Sheet |
| Post-Retrofit Chiller Max kW | 282 | kW | From York Manual |
| Post-Retrofit Cooling Tower Approach Temperature | 5.7 | F | Application |
| Baseline Chiller Efficiency | 0.748 | kW/ton | Title 24 Nominal Efficiency for Chiller > 300 Tons |
| | | | |
| Chiller AM Lockout | 7:00 | AM | Contact provided schedule; Chiller is on Manual Operation |
| Chiller PM Lockout | 6:00 | PM | Contact provided schedule; Chiller is on Manual Operation |
| Chiller Startup OSA Temperature | 60 | F | Contact provided estimate |
| Chiller Max Load OSA Temperature | 112 | F | Contact provided estimate |
| Chilled Water Supply Temperature Setpoint | 50 | F | Contact provided setpoints; Chiller is on Manual Operation |
| Condenser Water Temperature | 90 | F | Contact provided setpoints; Chiller is on Manual Operation |
| Date of Chiller Installation | 8/15/98 | | Contact provided estimate |
| Date at Run Hour Reading | 8/10/99 | | Chiller Log |
| Number of Days Chiller Operated | 247 | days (M-F Only) | = ((Read Date - Install Date) * 5/7) - 10 Holidays |
| Run Hours for New Chiller | 2324 | hours | Documented from Chiller Log |
| Average Hours per Year of Chiller Operation | 2451.62 | Hours/Year (M-F Only) | = (Run Hours for New Chiller / Number of Days Chiller Operated) * 365 Days/Year * 5/7 |
| | | | |
| Predicted Run Hours Since Install Using Actual Weather & Setpoints | 2442.00 | hours | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |
| Predicted Hours per Year Using Actual Weather Data & Setpoints | 2483.50 | Hours/Year (M-F Only) | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |

Site 2462: Post-Retrofit Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.551 |
| Nom. Tons | 500 |
| nom kw | 275.5 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 500 | 90 | 50 | 480 | 1.000 | 1.00 | 0.97 | 0.1520 | 6.58 | 0.534 |
| 107 | 459 | 89 | 49.5 | 483 | 0.918 | 0.91 | 0.97 | 0.1504 | 6.65 | 0.529 |
| 102 | 414 | 88 | 49 | 486 | 0.827 | 0.82 | 0.96 | 0.1493 | 6.70 | 0.525 |
| 97 | 368 | 87 | 48.5 | 488 | 0.736 | 0.73 | 0.95 | 0.1489 | 6.72 | 0.524 |
| 92 | 323 | 86 | 48 | 491 | 0.645 | 0.65 | 0.95 | 0.1496 | 6.68 | 0.526 |
| 87 | 277 | 85 | 47.5 | 493 | 0.555 | 0.57 | 0.94 | 0.1519 | 6.58 | 0.534 |
| 82 | 232 | 84 | 47 | 495 | 0.464 | 0.50 | 0.94 | 0.1566 | 6.38 | 0.551 |
| 77 | 186 | 83 | 46.5 | 497 | 0.373 | 0.42 | 0.93 | 0.1656 | 6.04 | 0.582 |
| 72 | 141 | 82 | 46 | 499 | 0.282 | 0.36 | 0.92 | 0.1829 | 5.47 | 0.643 |
| 67 | 95 | 81 | 45.5 | 500 | 0.191 | 0.29 | 0.92 | 0.2202 | 4.54 | 0.774 |
| 62 | 50 | 80 | 45 | 501 | 0.100 | 0.23 | 0.91 | 0.3324 | 3.01 | 1.169 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2462: Baseline Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 500 |
| nom kw | 374.042553 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 500 | 90 | 50 | 480 | 1.000 | 1.00 | 0.97 | 0.2063 | 4.85 | 0.726 |
| 107 | 459 | 89 | 49.5 | 483 | 0.918 | 0.91 | 0.97 | 0.2042 | 4.90 | 0.718 |
| 102 | 414 | 88 | 49 | 486 | 0.827 | 0.82 | 0.96 | 0.2027 | 4.93 | 0.713 |
| 97 | 368 | 87 | 48.5 | 488 | 0.736 | 0.73 | 0.95 | 0.2022 | 4.95 | 0.711 |
| 92 | 323 | 86 | 48 | 491 | 0.645 | 0.65 | 0.95 | 0.2031 | 4.92 | 0.714 |
| 87 | 277 | 85 | 47.5 | 493 | 0.555 | 0.57 | 0.94 | 0.2062 | 4.85 | 0.725 |
| 82 | 232 | 84 | 47 | 495 | 0.464 | 0.50 | 0.94 | 0.2127 | 4.70 | 0.748 |
| 77 | 186 | 83 | 46.5 | 497 | 0.373 | 0.42 | 0.93 | 0.2248 | 4.45 | 0.791 |
| 72 | 141 | 82 | 46 | 499 | 0.282 | 0.36 | 0.92 | 0.2483 | 4.03 | 0.873 |
| 67 | 95 | 81 | 45.5 | 500 | 0.191 | 0.29 | 0.92 | 0.2990 | 3.34 | 1.051 |
| 62 | 50 | 80 | 45 | 501 | 0.100 | 0.23 | 0.91 | 0.4512 | 2.22 | 1.587 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2462: Pre-Retrofit Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 1 |
| Nom. Tons | 150 |
| nom kw | 150 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 150 | 90 | 50 | 144 | 1.000 | 1.00 | 0.97 | 0.2758 | 3.63 | 0.970 |
| 107 | 138 | 89 | 49.5 | 145 | 0.918 | 0.91 | 0.97 | 0.2729 | 3.66 | 0.960 |
| 102 | 124 | 88 | 49 | 146 | 0.827 | 0.82 | 0.96 | 0.2709 | 3.69 | 0.952 |
| 97 | 110 | 87 | 48.5 | 146 | 0.736 | 0.73 | 0.95 | 0.2702 | 3.70 | 0.950 |
| 92 | 97 | 86 | 48 | 147 | 0.645 | 0.65 | 0.95 | 0.2715 | 3.68 | 0.955 |
| 87 | 83 | 85 | 47.5 | 148 | 0.555 | 0.57 | 0.94 | 0.2757 | 3.63 | 0.969 |
| 82 | 70 | 84 | 47 | 149 | 0.464 | 0.50 | 0.94 | 0.2843 | 3.52 | 0.999 |
| 77 | 56 | 83 | 46.5 | 149 | 0.373 | 0.42 | 0.93 | 0.3006 | 3.33 | 1.057 |
| 72 | 42 | 82 | 46 | 150 | 0.282 | 0.36 | 0.92 | 0.3319 | 3.01 | 1.167 |
| 67 | 29 | 81 | 45.5 | 150 | 0.191 | 0.29 | 0.92 | 0.3997 | 2.50 | 1.405 |
| 62 | 15 | 80 | 45 | 150 | 0.100 | 0.23 | 0.91 | 0.6032 | 1.66 | 2.121 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2462: Weather Data

TMY temperature data for climate zone 13

| Temp | 0:00 | 1:00 | 2.00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | 1 | 3 | 3 | | | | | | | | | | | | | | | | | | |
| 32 | 4 | 6 | 10 | 14 | 15 | 19 | 19 | 7 | | | | | | | | | | | | | 2 | 4 | 4 | 4 | |
| 37 | 27 | 32 | 34 | 34 | 37 | 32 | 31 | 26 | 17 | 8 | 1 | | | | | | | 2 | 5 | 7 | 6 | 9 | 17 | 26 | |
| 42 | 41 | 40 | 36 | 41 | 37 | 42 | 43 | 34 | 24 | 19 | 13 | 8 | 3 | 3 | 3 | 3 | 5 | 7 | 10 | 19 | 27 | 31 | 32 | 32 | |
| 47 | 50 | 54 | 64 | 65 | 65 | 55 | 48 | 45 | 38 | 24 | 20 | 15 | 11 | 9 | 9 | 8 | 14 | 19 | 29 | 26 | 33 | 42 | 49 | 50 | |
| 52 | 61 | 61 | 61 | 59 | 56 | 53 | 49 | 48 | 49 | 48 | 41 | 35 | 25 | 24 | 21 | 23 | 30 | 45 | 41 | 59 | 58 | 60 | 56 | 55 | |
| 57 | 43 | 42 | 41 | 44 | 48 | 42 | 38 | 39 | 36 | 39 | 46 | 46 | 42 | 41 | 41 | 39 | 42 | 42 | 49 | 43 | 47 | 37 | 44 | 50 | |
| 62 | 35 | 44 | 52 | 63 | 55 | 46 | 39 | 36 | 37 | 35 | 36 | 37 | 39 | 38 | 43 | 37 | 41 | 36 | 40 | 38 | 36 | 40 | 29 | 33 | 415 |
| 67 | 53 | 52 | 40 | 21 | 33 | 47 | 48 | 39 | 37 | 31 | 26 | 27 | 36 | 39 | 31 | 36 | 33 | 32 | 28 | 25 | 22 | 28 | 39 | 39 | 367 |
| 72 | 33 | 26 | 22 | 23 | 17 | 20 | 27 | 41 | 42 | 37 | 33 | 33 | 26 | 23 | 27 | 25 | 24 | 27 | 25 | 32 | 33 | 37 | 47 | 42 | 338 |
| 77 | 15 | 8 | 5 | 1 | 1 | 6 | 18 | 35 | 39 | 41 | 39 | 36 | 29 | 30 | 27 | 26 | 25 | 24 | 32 | 30 | 43 | 42 | 29 | 25 | 351 |
| 82 | 3 | | | 0 | | | 2 | 13 | 33 | 45 | 44 | 35 | 39 | 36 | 35 | 35 | 30 | 35 | 28 | 38 | 39 | 27 | 18 | 9 | 380 |
| 87 | | | | | | | | 2 | 12 | 31 | 38 | 42 | 39 | 31 | 27 | 29 | 38 | 27 | 42 | 36 | 17 | 8 | 1 | | 314 |
| 92 | | | | | | | | | 1 | 6 | 25 | 36 | 37 | 39 | 42 | 43 | 39 | 37 | 26 | 12 | 2 | | | | 305 |
| 97 | | | | | | | | | | | 3 | 15 | 31 | 36 | 38 | 31 | 27 | 27 | 10 | | | | | | 206 |
| 102 | | | | | | | | | | | | | 8 | 15 | 22 | 27 | 19 | 5 | | | | | | | 96 |
| 107 | | | | | | | | | | | | | | 1 | 1 | 3 | | | | | | | | | 5 |
| 112 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| On Hours | | | | | | | | 166 | 201 | 226 | 244 | 261 | 284 | 288 | 291 | 292 | 274 | 125 | | | | | | | 2777.00 |

Actual temperature data for climate zone 13 for 8/15/98 to 8/10/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | . | . | 1 | 1 | 1 | 2 | 1 | . | . | . | | . | . | . | . | . | . | . | . | . | . | . | . | |
| 27 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 1 | 1 | . | . | . | . | . | . | . | . | . | 1 | 1 | 2 | 3 | |
| 32 | 9 | 9 | 15 | 16 | 15 | 19 | 18 | 16 | 12 | 6 | 2 | 3 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 4 | 2 | 5 | 4 | 5 | |
| 37 | 15 | 21 | 17 | 20 | 27 | 30 | 31 | 28 | 21 | 16 | 13 | 9 | 6 | 3 | 3 | 3 | 5 | 7 | 9 | 11 | 14 | 18 | 19 | 17 | |
| 42 | 33 | 37 | 39 | 37 | 40 | 40 | 44 | 29 | 24 | 18 | 11 | 10 | 12 | 11 | 7 | 6 | 9 | 9 | 12 | 13 | 18 | 16 | 23 | 25 | |
| 47 | 49 | 54 | 59 | 57 | 55 | 50 | 44 | 52 | 39 | 31 | 23 | 16 | 12 | 13 | 15 | 17 | 16 | 20 | 23 | 29 | 26 | 35 | 36 | 49 | |
| 52 | 55 | 44 | 43 | 55 | 57 | 60 | 47 | 41 | 48 | 49 | 43 | 34 | 25 | 16 | 18 | 18 | 24 | 26 | 39 | 43 | 56 | 54 | 58 | 56 | |
| 57 | 41 | 51 | 50 | 45 | 45 | 41 | 48 | 38 | 35 | 40 | 47 | 51 | 55 | 48 | 41 | 45 | 43 | 51 | 51 | 46 | 44 | 44 | 40 | 40 | |
| 62 | 40 | 36 | 39 | 41 | 40 | 39 | 34 | 34 | 39 | 27 | 38 | 38 | 32 | 42 | 46 | 41 | 42 | 39 | 29 | 33 | 27 | 31 | 42 | 39 | 394.5 |
| 67 | 33 | 39 | 39 | 41 | 41 | 42 | 40 | 33 | 30 | 42 | 24 | 29 | 37 | 37 | 35 | 34 | 30 | 26 | 22 | 28 | 32 | 34 | 33 | 34 | 344 |
| 72 | 42 | 34 | 29 | 24 | 20 | 18 | 22 | 39 | 30 | 31 | 39 | 32 | 20 | 18 | 23 | 23 | 19 | 22 | 30 | 30 | 36 | 28 | 27 | 36 | 285 |
| 77 | 19 | 16 | 17 | 14 | 12 | 13 | 20 | 21 | 38 | 27 | 28 | 30 | 38 | 38 | 31 | 26 | 32 | 36 | 30 | 33 | 27 | 31 | 41 | 29 | 323 |
| 82 | 14 | 13 | 9 | 5 | 4 | 4 | 7 | 19 | 25 | 38 | 38 | 32 | 29 | 27 | 27 | 33 | 32 | 26 | 30 | 21 | 30 | 37 | 17 | 16 | 313 |
| 87 | 8 | 4 | 2 | 2 | 1 | 1 | 2 | 6 | 14 | 21 | 28 | 33 | 33 | 30 | 28 | 28 | 24 | 23 | 25 | 41 | 28 | 16 | 13 | 11 | 256.5 |
| 92 | . | . | . | . | . | . | . | 1 | 6 | 10 | 19 | 25 | 33 | 34 | 34 | 33 | 34 | 39 | 38 | 21 | 14 | 10 | 6 | 1 | 247.5 |
| 97 | . | . | . | . | . | . | . | . | . | 4 | 7 | 15 | 17 | 25 | 29 | 30 | 31 | 24 | 14 | 10 | 6 | 1 | . | . | 170 |
| 102 | . | . | . | . | . | . | . | . | . | . | 2 | 6 | 12 | 14 | 16 | 14 | 14 | 11 | 7 | . | . | . | . | . | 82.5 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 3 | 8 | 9 | 5 | . | . | . | . | . | . | . | 26 |
| 112 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| On Hours | | | | | | | | 153 | 179 | 200 | 221 | 238 | 250 | 268 | 276 | 271 | 263 | 123 | | | | | | | 2442.00 |

Actual temperature data for climate zone 13 for 8/11/98 to 8/10/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16.00 | 17.00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | . | . | . | 1 | 1 | 1 | 2 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 27 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 1 | 1 | . | . | . | . | . | . | . | . | . | 1 | 1 | 2 | 3 | |
| 32 | 9 | 9 | 15 | 16 | 15 | 19 | 18 | 16 | 12 | 6 | 2 | 3 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 4 | 2 | 5 | 4 | 5 | |
| 37 | 15 | 21 | 17 | 20 | 27 | 30 | 31 | 28 | 21 | 16 | 13 | 9 | 6 | 3 | 3 | 3 | 5 | 7 | 9 | 11 | 14 | 18 | 19 | 17 | |
| 42 | 33 | 37 | 39 | 37 | 40 | 40 | 44 | 29 | 24 | 18 | 11 | 10 | 12 | 11 | 7 | 6 | 9 | 9 | 12 | 13 | 18 | 16 | 23 | 25 | |
| 47 | 49 | 54 | 59 | 57 | 55 | 50 | 44 | 52 | 39 | 31 | 23 | 16 | 12 | 13 | 15 | 17 | 16 | 20 | 23 | 29 | 26 | 35 | 36 | 49 | |
| 52 | 55 | 44 | 43 | 55 | 57 | 60 | 47 | 41 | 48 | 49 | 43 | 34 | 25 | 16 | 18 | 18 | 24 | 26 | 39 | 43 | 56 | 54 | 58 | 56 | |
| 57 | 41 | 51 | 50 | 45 | 45 | 41 | 48 | 38 | 35 | 40 | 47 | 51 | 55 | 48 | 41 | 45 | 43 | 51 | 51 | 46 | 44 | 44 | 40 | 40 | |
| 62 | 40 | 36 | 39 | 41 | 40 | 39 | 34 | 34 | 39 | 27 | 36 | 36 | 32 | 42 | 46 | 41 | 42 | 39 | 29 | 33 | 27 | 31 | 42 | 39 | 394.5 |
| 67 | 33 | 39 | 39 | 41 | 41 | 42 | 40 | 33 | 30 | 42 | 24 | 29 | 37 | 37 | 35 | 34 | 30 | 26 | 22 | 26 | 32 | 34 | 33 | 34 | 344 |
| 72 | 42 | 34 | 29 | 24 | 20 | 18 | 22 | 39 | 30 | 31 | 39 | 32 | 20 | 18 | 23 | 23 | 19 | 22 | 30 | 30 | 36 | 28 | 27 | 36 | 285 |
| 77 | 19 | 16 | 18 | 15 | 14 | 15 | 21 | 21 | 36 | 27 | 28 | 30 | 36 | 38 | 31 | 26 | 32 | 36 | 30 | 33 | 27 | 31 | 41 | 29 | 323 |
| 82 | 16 | 15 | 11 | 8 | 6 | 6 | 10 | 21 | 25 | 38 | 38 | 32 | 29 | 27 | 27 | 33 | 32 | 26 | 30 | 21 | 30 | 37 | 17 | 16 | 315 |
| 87 | 10 | 6 | 3 | 2 | 1 | 1 | 2 | 8 | 16 | 22 | 28 | 33 | 33 | 30 | 28 | 28 | 24 | 23 | 25 | 41 | 28 | 17 | 14 | 14 | 261.5 |
| 92 | . | . | . | . | . | . | . | 1 | 7 | 13 | 20 | 26 | 33 | 34 | 34 | 33 | 34 | 39 | 38 | 21 | 16 | 13 | 9 | 2 | 254.5 |
| 97 | . | . | . | . | . | . | . | . | . | 4 | 10 | 17 | 18 | 25 | 29 | 30 | 31 | 24 | 15 | 14 | 8 | 1 | . | . | 176 |
| 102 | . | . | . | . | . | . | . | . | . | . | 2 | 7 | 15 | 18 | 16 | 16 | 16 | 14 | 10 | . | . | . | . | . | 96 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 3 | 11 | 12 | 7 | 1 | . | . | . | . | . | . | 34 |
| 112 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| On Hours | | | | | | | | 157 | 183 | 204 | 225 | 242 | 254 | 272 | 280 | 275 | 267 | 125 | | | | | | | 2483.50 |

**Chiller Replacement (Site 2463)**

| | |
|---|---|
| Program | Retrofit Efficiency Options Program |
| Measure | High Efficiency Water-Cooled Chiller |
| Site Description | Office |

**Measure Description**

Replace existing water-cooled chiller with a 164-ton high-efficiency water-cooled chiller.

**Summary of Ex Ante Impact Calculations**

Tables of standard values were developed using the HBSSM simulation program based on climate zone, chiller size, building type, chiller efficiency, and condenser water temperature. Values from these tables are used to calculate the rebate and associated impacts.

**Comments on PG&E Calculations**

The application calculations used the correct climate zone, chiller size and building characteristics.

**Evaluation Process**

The evaluation process consists of a review of the application form and supporting documentation, conducting an on-site survey and then computing impacts using the on-site data.

The on-site survey was conducted on August 9, 1999 in Bakersfield (Climate Zone 13). Information on the retrofit equipment and operating conditions was collected through an inspection of the chillers and through an interview with the Air Conditioning and Plumbing Lead Worker.

Discussions provided data for development of a relationship between chiller loading and outdoor dry bulb. The chiller is available from 6:00 am to 10:00 pm, Monday through Friday. The chiller is available on weekends from 8:00 am to 4:00 pm. The chiller is brought on line at 70 degrees F outside air temperature. The contact stated that the chiller is fully loaded at approximately 105 degrees F.

Models are calibrated with actual weather, observed chiller run hours since the installation, chiller loading under extreme outdoor temperature conditions, chilled water temperature, and condenser water temperature. Energy impacts are based on typical weather data. A Title 24 baseline, nominal efficiency, and typical year bin weather data for the applicable climate zone are used in the bin analysis. To compute the impacts, the following assumptions were used:

- A linear loading strategy was used for the analysis of both the baseline and rebated chillers, which assumed initial loading at 70 degrees F and 100% loading at 105 degrees F.
- The minimum operating load for the chiller is 25%.
- Based on a water-cooled screw chiller between 150 and 300 tons, a baseline Title 24 efficiency of 0.837 KW/ton was used.

Chiller efficiencies at various temperatures were calculated from updated default performance coefficients provided in a memo to the California Energy Commission titled "1995 Proposed Changes to the ACM Manual Central Plant Cooling Equipment" by Mark Hydeman. These coefficients were used to develop a chiller efficiency curve for the Rebate case and a Title 24 base case. Evaluation-based energy and demand impacts were slightly higher than Ex Ante estimates. The discrepancy is most likely due to the actual operating hours of the facility. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| MDSS | 27.13 | 49,917.75 | 0 |
| Adjusted Engineering | 36 | 59,870 | 0 |
| Engineering Realization Rate | 1.33 | 1.20 | N/A |

Site 2463: Results

| Post-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.59 |
| Nom. Tons | 164 |
| nom kw | 96.76 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 107 | 0.00 | 164 | 0.53 | 0.00 | 86.23 | 5.00 | 431.17 |
| 102 | 45.00 | 146 | 0.52 | 3,433.29 | 76.30 | 51.00 | 3,891.06 |
| 97 | 146.00 | 129 | 0.52 | 9,820.67 | 67.26 | 93.00 | 6,255.63 |
| 92 | 294.00 | 111 | 0.53 | 17,385.30 | 59.13 | 135.00 | 7,983.05 |
| 87 | 447.00 | 94 | 0.55 | 23,197.14 | 51.90 | 244.00 | 12,662.42 |
| 82 | 702.00 | 76 | 0.60 | 31,972.48 | 45.54 | 326.00 | 14,847.62 |
| 77 | 697.00 | 59 | 0.68 | 27,936.05 | 40.08 | 418.00 | 16,753.61 |
| 72 | 822.00 | 41 | 0.87 | 29,182.37 | 35.50 | 439.00 | 15,585.23 |
| Totals | 3,108.00 | | | 142,927.30 | 86.23 | 1,711.00 | 78,409.79 |

| | Energy | | Demand | |
|---|---|---|---|---|
| | Savings | Impact | Savings | Impact |
| MDSS | | 49,918 | | 27.132 |
| QC | 41,928 | 59,870 | 46 | 36 |
| Realization Rate | | 1.20 | | 1.33 |

| Title 24 Baseline Chiller | |
|---|---|
| Nom. Eff | 0.837 |
| Nom. Tons | 164 |
| nom kw | 137.291 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 107 | 0.00 | 164 | 0.75 | 0.00 | 122.36 |
| 102 | 45.00 | 146 | 0.74 | 4,871.44 | 108.25 |
| 97 | 146.00 | 129 | 0.74 | 13,934.41 | 95.44 |
| 92 | 294.00 | 111 | 0.75 | 24,667.76 | 83.90 |
| 87 | 447.00 | 94 | 0.79 | 32,914.10 | 73.63 |
| 82 | 702.00 | 76 | 0.85 | 45,365.31 | 64.62 |
| 77 | 697.00 | 59 | 0.97 | 39,638.07 | 56.87 |
| 72 | 822.00 | 41 | 1.23 | 41,406.47 | 50.37 |
| Totals | 3,153.00 | | | 202,797.57 | 122.36 |

| Pre-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.9 |
| Nom. Tons | 165 |
| nom kw | 148.5 |

| Outdoor DB Temperature (F) | Operating Hours per year (Actual) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 107 | 5.00 | 165 | 0.80 | 661.72 | 132.34 |
| 102 | 51.00 | 147 | 0.79 | 5,971.70 | 117.09 |
| 97 | 93.00 | 130 | 0.80 | 9,600.67 | 103.23 |
| 92 | 135.00 | 112 | 0.81 | 12,251.78 | 90.75 |
| 87 | 244.00 | 94 | 0.84 | 19,433.33 | 79.64 |
| 82 | 326.00 | 77 | 0.91 | 22,787.01 | 69.90 |
| 77 | 418.00 | 59 | 1.04 | 25,712.19 | 61.51 |
| 72 | 439.00 | 41 | 1.32 | 23,919.05 | 54.49 |
| Totals | 1711.00 | | | 120,337.47 | 132.34 |

Site 2463: Inputs to Model

| Parameter | Value Reported | Units of Parameter | Notes |
|---|---|---|---|
| City | Bakersfield | | |
| Climate Zone | 12 | Belmont | |
| Pre-Retrofit Nominal Chiller Capacity | 165 | Tons | Contact provided estimate |
| Pre-Retrofit Nominal Chiller Efficiency | 0.9 | kW/ton | Contact provided estimate |
| | | | |
| Post-Retrofit Nominal Chiller Capacity | 164 | Tons | Application |
| Post-Retrofit Nominal Chiller Efficiency | 0.59 | kW/ton | From Chiller Rating Sheet |
| Baseline Chiller Efficiency | 0.837 | kW/ton | Title 24 Nominal Efficiency for Chiller > 300 Tons |
| | | | |
| Chiller AM Lockout | 6:00 | AM | M-F |
| Chiller AM Lockout | 8:00 | AM | Sat, Sun |
| Chiller PM Lockout | 10:00 | PM | M-F |
| Chiller PM Lockout | 4:00 | PM | Sat, Sun |
| Chiller Startup OSA Temperature | 70 | F | Contact provided estimate |
| Chiller Max Load OSA Temperature | 105 | F | Contact provided estimate |
| Chilled Water Supply Temperature Setpoint | 44 | F | Contact proviced setpoints |
| Condenser Water Temperature Setpoint | 85 | F | Contact provided setpoints |
| Date of Chiller Installation | 9/10/97 | | Contact provided estimate |
| Date at Run Hour Reading | 8/9/99 | | Chiller Log |
| Number of Days Chiller Operated | 698 | days | = Read Date - Install Date |
| Run Hours for New Chiller | 2823 | hours | Documented from Chiller Log |
| Average Hours per Year of Chiller Operation | 1476.21 | | = (Run Hours for New Chiller / Number of Days Chiller Operated) * 365 Days/Year |
| | | | |
| Predicted Run Hours Since Install Using Actual Weather & Setpoints | 3077.00 | hours | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |
| Predicted Hours per Year Using Actual Weather Data & Setpoints | 1711.00 | Hours/Year | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |

Site 2463: Post-Retrofit Chiller

| Screw Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

| | |
|---|---|
| Nom. Eff | 0.59 |
| Nom. Tons | 164 |
| nom kw | 96.76 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 107 | 164 | 85 | 54.5 | 196 | 1.000 | 1.03 | 0.87 | 0.1496 | 6.69 | 0.526 |
| 102 | 146 | 84 | 53 | 192 | 0.893 | 0.91 | 0.87 | 0.1482 | 6.75 | 0.521 |
| 97 | 129 | 83 | 51.5 | 189 | 0.786 | 0.80 | 0.87 | 0.1485 | 6.74 | 0.522 |
| 92 | 111 | 82 | 50 | 185 | 0.679 | 0.70 | 0.87 | 0.1511 | 6.62 | 0.531 |
| 87 | 94 | 81 | 48.5 | 181 | 0.571 | 0.62 | 0.87 | 0.1575 | 6.35 | 0.554 |
| 82 | 76 | 80 | 47 | 177 | 0.464 | 0.54 | 0.87 | 0.1701 | 5.88 | 0.598 |
| 77 | 59 | 79 | 45.5 | 174 | 0.357 | 0.47 | 0.88 | 0.1946 | 5.14 | 0.684 |
| 72 | 41 | 78 | 44 | 170 | 0.250 | 0.42 | 0.88 | 0.2463 | 4.06 | 0.866 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |
| EIRFPLR | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2463: Baseline Chiller

| Screw Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

| | |
|---|---|
| Nom. Eff | 0.837 |
| Nom. Tons | 164 |
| nom kw | 137.291429 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 107 | 164 | 85 | 54.5 | 196 | 1.000 | 1.03 | 0.87 | 0.2122 | 4.71 | 0.746 |
| 102 | 146 | 84 | 53 | 192 | 0.893 | 0.91 | 0.87 | 0.2103 | 4.76 | 0.739 |
| 97 | 129 | 83 | 51.5 | 189 | 0.786 | 0.80 | 0.87 | 0.2107 | 4.75 | 0.741 |
| 92 | 111 | 82 | 50 | 185 | 0.679 | 0.70 | 0.87 | 0.2144 | 4.66 | 0.754 |
| 87 | 94 | 81 | 48.5 | 181 | 0.571 | 0.62 | 0.87 | 0.2235 | 4.47 | 0.786 |
| 82 | 76 | 80 | 47 | 177 | 0.464 | 0.54 | 0.87 | 0.2414 | 4.14 | 0.849 |
| 77 | 59 | 79 | 45.5 | 174 | 0.357 | 0.47 | 0.88 | 0.2762 | 3.62 | 0.971 |
| 72 | 41 | 78 | 44 | 170 | 0.250 | 0.42 | 0.88 | 0.3494 | 2.86 | 1.229 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |
| EIRFPLR | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2463: Pre-Retrofit Chiller

| Screw Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

| | |
|---|---|
| Nom. Eff | 0.9 |
| Nom. Tons | 165 |
| nom kw | 148.5 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 107 | 165 | 85 | 54.5 | 197 | 1.000 | 1.03 | 0.87 | 0.2281 | 4.38 | 0.802 |
| 102 | 147 | 84 | 53 | 193 | 0.893 | 0.91 | 0.87 | 0.2261 | 4.42 | 0.795 |
| 97 | 130 | 83 | 51.5 | 190 | 0.786 | 0.80 | 0.87 | 0.2265 | 4.42 | 0.796 |
| 92 | 112 | 82 | 50 | 186 | 0.679 | 0.70 | 0.87 | 0.2305 | 4.34 | 0.811 |
| 87 | 94 | 81 | 48.5 | 182 | 0.571 | 0.62 | 0.87 | 0.2403 | 4.16 | 0.845 |
| 82 | 77 | 80 | 47 | 178 | 0.464 | 0.54 | 0.87 | 0.2595 | 3.85 | 0.912 |
| 77 | 59 | 79 | 45.5 | 175 | 0.357 | 0.47 | 0.88 | 0.2969 | 3.37 | 1.044 |
| 72 | 41 | 78 | 44 | 171 | 0.250 | 0.42 | 0.88 | 0.3757 | 2.66 | 1.321 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients – Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual – Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |
| EIRFPLR | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2463: Weekday Weather Data

TMY temperature data for climate zone 13

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 27 | . | . | . | 3 | 3 | 3 | 6 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 32 | 9 | 8 | 12 | 13 | 14 | 15 | 16 | 11 | . | . | . | . | . | . | . | . | . | . | . | . | . | 2 | 4 | 7 | |
| 37 | 20 | 27 | 31 | 34 | 36 | 37 | 34 | 24 | 16 | 7 | . | . | . | . | . | . | . | . | . | 4 | 10 | 15 | 15 | 15 | |
| 42 | 54 | 61 | 64 | 62 | 61 | 60 | 59 | 46 | 47 | 31 | 18 | 7 | 4 | 4 | 1 | 2 | 3 | 10 | 21 | 26 | 29 | 31 | 44 | 51 | |
| 47 | 75 | 67 | 70 | 76 | 73 | 62 | 55 | 54 | 39 | 37 | 37 | 30 | 19 | 13 | 15 | 17 | 25 | 32 | 40 | 39 | 49 | 58 | 63 | 70 | |
| 52 | 72 | 78 | 85 | 85 | 80 | 87 | 59 | 49 | 49 | 52 | 42 | 35 | 31 | 35 | 36 | 31 | 36 | 45 | 52 | 62 | 65 | 76 | 72 | 67 | |
| 57 | 83 | 78 | 67 | 61 | 68 | 60 | 71 | 55 | 43 | 36 | 48 | 51 | 45 | 43 | 41 | 42 | 45 | 50 | 48 | 55 | 65 | 61 | 80 | 88 | |
| 62 | 33 | 27 | 22 | 22 | 22 | 31 | 42 | 69 | 48 | 35 | 32 | 35 | 46 | 49 | 46 | 44 | 43 | 36 | 50 | 54 | 62 | 72 | 56 | 44 | |
| 67 | 14 | 15 | 12 | 9 | 8 | 8 | 17 | 32 | 64 | 52 | 37 | 36 | 31 | 26 | 27 | 28 | 37 | 42 | 40 | 59 | 50 | 29 | 19 | 15 | |
| 72 | 5 | 4 | 2 | . | . | 2 | **5** | **18** | **37** | **57** | **44** | **36** | **30** | **33** | **34** | **37** | **32** | **32** | **49** | **33** | **20** | **17** | 10 | 8 | 514 |
| 77 | . | . | . | . | . | . | **1** | **7** | **14** | **36** | **52** | **47** | **34** | **32** | **31** | **25** | **33** | **48** | **28** | **21** | **14** | **3** | 2 | . | 426 |
| 82 | . | . | . | . | . | . | . | . | **8** | **14** | **33** | **46** | **58** | **46** | **43** | **47** | **47** | **31** | **22** | **10** | **1** | **1** | . | . | 407 |
| 87 | . | . | . | . | . | . | . | . | . | **8** | **15** | **24** | **32** | **40** | **39** | **35** | **28** | **22** | **9** | **2** | . | . | . | . | 254 |
| 92 | . | . | . | . | . | . | . | . | . | . | **7** | **14** | **21** | **25** | **27** | **35** | **22** | **9** | **5** | . | . | . | . | . | 165 |
| 97 | . | . | . | . | . | . | . | . | . | . | . | **4** | **14** | **15** | **19** | **13** | **9** | **6** | **1** | . | . | . | . | . | 81 |
| 102 | . | . | . | . | . | . | . | . | . | . | . | . | . | **4** | **6** | **9** | **5** | **2** | . | . | . | . | . | . | 26 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| On Hours | | | | | | | 6 | 25 | 59 | 115 | 151 | 171 | 189 | 195 | 199 | 201 | 176 | 150 | 114 | 66 | 35 | 21 | | | **1337.86** |

Actual temperature by hour from 09/10/97 to 08/09/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | . | . | . | . | . | . | 1 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 27 | 2 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | . | . | . | . | . | . | . | . | . | . | . | . | . | 2 | 3 | |
| 32 | 3 | 5 | 4 | 6 | 8 | 10 | 9 | 7 | 2 | 4 | 1 | . | . | . | . | . | . | . | . | 1 | 2 | 4 | 2 | 2 | |
| 37 | 16 | 19 | 21 | 24 | 24 | 25 | 22 | 20 | 16 | 7 | 8 | 8 | 4 | 2 | 2 | 2 | 3 | 4 | 7 | 8 | 8 | 6 | 8 | 11 | |
| 42 | 26 | 24 | 31 | 31 | 29 | 29 | 32 | 26 | 22 | 16 | 7 | 2 | 4 | 5 | 3 | 3 | 4 | 5 | 4 | 6 | 13 | 18 | 22 | 29 | |
| 47 | 42 | 39 | 36 | 41 | 46 | 40 | 34 | 34 | 31 | 30 | 24 | 18 | 8 | 9 | 8 | 8 | 10 | 14 | 22 | 25 | 31 | 34 | 41 | 40 | |
| 52 | 38 | 48 | 51 | 51 | 49 | 52 | 42 | 31 | 39 | 38 | 35 | 28 | 29 | 23 | 18 | 19 | 25 | 30 | 36 | 46 | 43 | 41 | 34 | 36 | |
| 57 | 62 | 60 | 58 | 53 | 58 | 52 | 55 | 37 | 19 | 25 | 30 | 39 | 44 | 42 | 45 | 45 | 39 | 42 | 41 | 33 | 33 | 44 | 53 | 54 | |
| 62 | 28 | 28 | 28 | 26 | 18 | 23 | 32 | 56 | 47 | 25 | 23 | 27 | 23 | 26 | 28 | 28 | 30 | 26 | 18 | 32 | 43 | 47 | 45 | 39 | |
| 67 | 18 | 13 | 9 | 8 | 7 | 6 | 9 | 16 | 41 | 44 | 31 | 13 | 17 | 18 | 20 | 19 | 16 | 15 | 33 | 37 | 34 | 25 | 23 | 20 | |
| 72 | 8 | 8 | 9 | 7 | 12 | 13 | **9** | **11** | **11** | **32** | **41** | **39** | **28** | **22** | **19** | **15** | **21** | **31** | **30** | **25** | **19** | **14** | 9 | 8 | 367 |
| 77 | 9 | 7 | 5 | 5 | 2 | 2 | **8** | **10** | **13** | **11** | **27** | **33** | **35** | **31** | **26** | **33** | **28** | **26** | **20** | **16** | **12** | **11** | 9 | 11 | 340 |
| 82 | 4 | 3 | 2 | 2 | 1 | 1 | **1** | **4** | **9** | **11** | **5** | **21** | **25** | **29** | **31** | **27** | **29** | **21** | **19** | **10** | **8** | **8** | 7 | 3 | 258 |
| 87 | . | . | . | . | . | . | . | **1** | **3** | **11** | **14** | **10** | **16** | **22** | **24** | **23** | **21** | **17** | **7** | **6** | **10** | **4** | 1 | . | 189 |
| 92 | . | . | . | . | . | . | . | . | **1** | **2** | **9** | **12** | **9** | **8** | **12** | **12** | **9** | **9** | **8** | **11** | . | . | . | . | 102 |
| 97 | . | . | . | . | . | . | . | . | . | . | **1** | **5** | **11** | **11** | **10** | **11** | **12** | **7** | **11** | . | . | . | . | . | 79 |
| 102 | . | . | . | . | . | . | . | . | . | . | . | **1** | **3** | **7** | **9** | **10** | **7** | **9** | . | . | . | . | . | . | 46 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | . | . | **1** | **1** | **1** | **2** | . | . | . | . | . | . | . | 5 |
| On Hours | | | | | | | 18 | 26 | 37 | 67 | 97 | 121 | 127 | 131 | 132 | 132 | 129 | 120 | 95 | 68 | 49 | 37 | | | **1386.00** |

Actual temperature by hour from 09/10/97 to 08/09/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | . | . | . | . | . | . | 1 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 27 | 2 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | . | . | . | . | . | . | . | . | . | . | . | . | . | 2 | 3 | |
| 32 | 3 | 5 | 5 | 8 | 10 | 11 | 10 | 9 | 2 | 4 | 1 | . | . | . | . | . | . | . | . | 1 | 2 | 4 | 2 | 2 | |
| 37 | 19 | 24 | 28 | 30 | 33 | 36 | 35 | 28 | 23 | 9 | 8 | 8 | 4 | 2 | 2 | 2 | 3 | 4 | 7 | 8 | 9 | 7 | 12 | 15 | |
| 42 | 47 | 47 | 57 | 63 | 59 | 58 | 58 | 49 | 37 | 23 | 12 | 4 | 6 | 5 | 3 | 3 | 4 | 5 | 6 | 10 | 20 | 27 | 29 | 43 | |
| 47 | 83 | 79 | 73 | 77 | 80 | 79 | 69 | 63 | 58 | 60 | 45 | 34 | 19 | 18 | 17 | 17 | 23 | 30 | 43 | 49 | 58 | 68 | 78 | 83 | |
| 52 | 84 | 101 | 108 | 110 | 111 | 111 | 100 | 82 | 79 | 83 | 82 | 64 | 60 | 53 | 44 | 48 | 54 | 68 | 81 | 92 | 90 | 85 | 84 | 80 | |
| 57 | 120 | 116 | 114 | 107 | 112 | 103 | 98 | 78 | 65 | 44 | 52 | 77 | 85 | 83 | 85 | 86 | 81 | 75 | 69 | 67 | 73 | 91 | 102 | 110 | |
| 62 | 58 | 54 | 47 | 44 | 40 | 47 | 60 | 92 | 76 | 66 | 55 | 49 | 44 | 53 | 60 | 55 | 54 | 56 | 50 | 68 | 85 | 87 | 79 | 73 | |
| 67 | 34 | 26 | 25 | 24 | 17 | 12 | 22 | 35 | 76 | 74 | 56 | 39 | 41 | 37 | 38 | 37 | 33 | 35 | 64 | 68 | 59 | 48 | 49 | 38 | |
| 72 | 17 | 16 | 17 | 13 | 18 | 21 | **18** | **20** | **22** | **60** | **73** | **64** | **52** | **44** | **39** | **34** | **47** | **58** | **50** | **47** | **38** | **30** | 21 | 17 | 696 |
| 77 | 12 | 11 | 7 | 5 | 2 | 3 | **11** | **17** | **24** | **21** | **48** | **62** | **62** | **55** | **48** | **58** | **48** | **47** | **38** | **31** | **22** | **20** | 16 | 16 | 612 |
| 82 | 6 | 4 | 2 | 2 | 1 | 1 | **1** | **8** | **13** | **20** | **14** | **36** | **47** | **53** | **52** | **46** | **50** | **38** | **36** | **17** | **15** | **12** | 8 | 5 | 458 |
| 87 | . | . | . | . | . | . | . | **1** | **6** | **17** | **22** | **17** | **26** | **35** | **43** | **43** | **40** | **29** | **13** | **12** | **12** | **5** | 3 | . | 321 |
| 92 | . | . | . | . | . | . | . | . | **2** | **3** | **14** | **20** | **17** | **15** | **21** | **20** | **13** | **15** | **12** | **13** | **2** | **1** | . | . | 168 |
| 97 | . | . | . | . | . | . | . | . | . | **1** | **3** | **9** | **16** | **19** | **17** | **18** | **19** | **10** | **14** | **2** | . | . | . | . | 128 |
| 102 | . | . | . | . | . | . | . | . | . | . | . | **2** | **5** | **11** | **14** | **15** | **12** | **13** | **1** | . | . | . | . | . | 73 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | . | **1** | **2** | **2** | **3** | **4** | **2** | **1** | . | . | . | . | . | 15 |
| On Hours | | | | | | | 30 | 46 | 67 | 122 | 174 | 210 | 226 | 234 | 236 | 237 | 233 | 212 | 165 | 122 | 89 | 68 | | | **2471.00** |

Site 2463: Weekend Weather Data

TMY temperature data for climate zone 13

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | 3 | 3 | 3 | 6 | | | | | | | | | | | | | | | | | | |
| 32 | 9 | 8 | 12 | 13 | 14 | 15 | 16 | 11 | | | | | | | | | | | | | | 2 | 4 | 7 | |
| 37 | 20 | 27 | 31 | 34 | 36 | 37 | 34 | 24 | 16 | 7 | | | | | | | | | | 4 | 10 | 15 | 15 | 15 | |
| 42 | 54 | 61 | 64 | 62 | 61 | 60 | 59 | 46 | 47 | 31 | 18 | 7 | 4 | 4 | 1 | 2 | 3 | 10 | 21 | 26 | 29 | 31 | 44 | 51 | |
| 47 | 75 | 67 | 70 | 76 | 73 | 62 | 55 | 54 | 39 | 37 | 37 | 30 | 19 | 13 | 15 | 17 | 25 | 32 | 40 | 39 | 49 | 58 | 63 | 70 | |
| 52 | 72 | 78 | 85 | 85 | 80 | 87 | 59 | 49 | 49 | 52 | 42 | 35 | 31 | 35 | 36 | 31 | 36 | 45 | 52 | 62 | 65 | 76 | 72 | 67 | |
| 57 | 83 | 78 | 67 | 61 | 68 | 60 | 71 | 55 | 43 | 36 | 48 | 51 | 45 | 43 | 41 | 42 | 45 | 50 | 48 | 55 | 65 | 61 | 80 | 88 | |
| 62 | 33 | 27 | 22 | 22 | 22 | 31 | 42 | 69 | 48 | 35 | 32 | 35 | 46 | 49 | 46 | 44 | 43 | 36 | 50 | 54 | 62 | 72 | 56 | 44 | |
| 67 | 14 | 15 | 12 | 9 | 8 | 8 | 17 | 32 | 64 | 52 | 37 | 36 | 31 | 26 | 27 | 28 | 37 | 42 | 40 | 59 | 50 | 29 | 19 | 15 | |
| 72 | 5 | 4 | 2 | | | 2 | 5 | 18 | **37** | **57** | **44** | **36** | **30** | **33** | **34** | **37** | 32 | 32 | 49 | 33 | 20 | 17 | 10 | 8 | 308 |
| 77 | | | | | | | 1 | 7 | **14** | **36** | **52** | **47** | **34** | **32** | **31** | **25** | 33 | 48 | 28 | 21 | 14 | 3 | 2 | | 271 |
| 82 | | | | | | | | | **8** | **14** | **33** | **46** | **58** | **46** | **43** | **47** | 47 | 31 | 22 | 10 | 1 | 1 | | | 295 |
| 87 | | | | | | | | | | **8** | **15** | **24** | **32** | **40** | **39** | **35** | 28 | 22 | 9 | 2 | | | | | 193 |
| 92 | | | | | | | | | | | **7** | **14** | **21** | **25** | **27** | **35** | 22 | 9 | 5 | | | | | | 129 |
| 97 | | | | | | | | | | | | **4** | **14** | **15** | **19** | **13** | 9 | 6 | 1 | | | | | | 65 |
| 102 | | | | | | | | | | | | | | **4** | **6** | **9** | 5 | 2 | | | | | | | 19 |
| 107 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| On Hours | | | | | | | | | 59 | 115 | 151 | 171 | 189 | 195 | 199 | 201 | | | | | | | | | **365.71** |

Actual temperature by hour from 09/01/98 to 08/31/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 32 | 3 | 2 | 1 | 1 | 1 | 3 | 4 | 5 | 2 | | | | | | | | | | | | | 1 | 2 | 2 | |
| 37 | 5 | 9 | 10 | 11 | 12 | 11 | 8 | 5 | 8 | 6 | 2 | 2 | 2 | 2 | 1 | | | 2 | 3 | 4 | 6 | 5 | 6 | 6 | |
| 42 | 11 | 8 | 12 | 11 | 11 | 10 | 11 | 9 | 4 | 6 | 9 | 4 | 3 | 3 | 3 | 4 | 4 | 3 | 2 | 4 | 3 | 6 | 5 | 6 | |
| 47 | 17 | 18 | 19 | 19 | 18 | 19 | 19 | 16 | 14 | 11 | 6 | 9 | 7 | 3 | 4 | 5 | 4 | 7 | 8 | 11 | 14 | 15 | 16 | 17 | |
| 52 | 21 | 23 | 21 | 25 | 25 | 22 | 20 | 20 | 19 | 17 | 13 | 10 | 10 | 12 | 10 | 10 | 13 | 14 | 18 | 16 | 16 | 17 | 20 | 22 | |
| 57 | 20 | 19 | 20 | 19 | 22 | 22 | 18 | 10 | 14 | 11 | 17 | 17 | 14 | 16 | 14 | 13 | 14 | 15 | 17 | 17 | 14 | 19 | 19 | 19 | |
| 62 | 13 | 11 | 11 | 9 | 7 | 10 | 13 | 20 | 9 | 12 | 9 | 10 | 15 | 12 | 15 | 13 | 15 | 12 | 8 | 13 | 18 | 17 | 13 | 14 | |
| 67 | 7 | 8 | 7 | 6 | 5 | 4 | 6 | 8 | 17 | 12 | 11 | 7 | 5 | 7 | 7 | 9 | 5 | 4 | 11 | 12 | 10 | 8 | 11 | 9 | |
| 72 | 5 | 4 | 2 | 2 | 2 | 3 | 3 | 6 | **7** | **15** | **10** | **10** | **11** | **7** | **6** | **6** | 8 | 13 | 9 | 7 | 10 | 6 | 6 | 3 | 72 |
| 77 | 2 | 2 | 1 | 1 | 1 | | 2 | 4 | **6** | **5** | **14** | **13** | **10** | **10** | **9** | **11** | 9 | 6 | 9 | 8 | 5 | 5 | 4 | 4 | 78 |
| 82 | | | | | | | | 1 | **3** | **8** | **5** | **11** | **11** | **10** | **11** | **9** | 8 | 12 | 8 | 4 | 4 | 3 | 1 | 2 | 68 |
| 87 | | | | | | | | | **1** | **1** | **7** | **7** | **9** | **10** | **10** | **10** | 10 | 4 | 3 | 5 | 3 | 1 | 1 | | 55 |
| 92 | | | | | | | | | | | **1** | **3** | **5** | **8** | **9** | **7** | 7 | 6 | 7 | 2 | 1 | 1 | | | 33 |
| 97 | | | | | | | | | | | | **1** | **2** | **3** | **4** | **4** | 4 | 5 | | 1 | | | | | 14 |
| 102 | | | | | | | | | | | | | | **1** | **1** | **3** | 3 | 1 | 1 | | | | | | 5 |
| 107 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| On Hours | | | | | | | | | 17 | 29 | 37 | 45 | 48 | 49 | 50 | 50 | | | | | | | | | **325.00** |

Actual temperature by hour from 08/10/98 to 08/09/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| 32 | 3 | 2 | 2 | 1 | 2 | 4 | 4 | 6 | 3 | | | | | | | | | | | | | 1 | 2 | 2 | |
| 37 | 8 | 12 | 13 | 15 | 14 | 14 | 12 | 8 | 10 | 8 | 3 | 2 | 2 | 2 | 1 | | | 2 | 3 | 4 | 6 | 5 | 7 | 7 | |
| 42 | 16 | 18 | 19 | 19 | 22 | 18 | 17 | 14 | 7 | 8 | 10 | 5 | 4 | 4 | 4 | 5 | 5 | 5 | 3 | 7 | 7 | 11 | 11 | 13 | |
| 47 | 37 | 37 | 40 | 44 | 42 | 44 | 42 | 34 | 30 | 20 | 13 | 12 | 10 | 4 | 5 | 7 | 6 | 11 | 19 | 20 | 28 | 28 | 32 | 34 | |
| 52 | 46 | 46 | 46 | 47 | 47 | 44 | 44 | 42 | 38 | 42 | 36 | 30 | 25 | 27 | 26 | 23 | 28 | 29 | 37 | 38 | 36 | 39 | 41 | 43 | |
| 57 | 37 | 36 | 38 | 37 | 41 | 42 | 30 | 26 | 28 | 18 | 27 | 30 | 29 | 32 | 28 | 30 | 31 | 31 | 26 | 29 | 27 | 33 | 34 | 42 | |
| 62 | 25 | 24 | 23 | 23 | 19 | 22 | 31 | 30 | 21 | 26 | 18 | 21 | 22 | 20 | 23 | 22 | 23 | 23 | 21 | 29 | 36 | 37 | 28 | 21 | |
| 67 | 16 | 15 | 13 | 8 | 8 | 6 | 10 | 20 | 32 | 24 | 25 | 17 | 18 | 19 | 19 | 17 | 16 | 15 | 23 | 21 | 16 | 13 | 18 | 18 | |
| 72 | 8 | 6 | 4 | 4 | 3 | 6 | 5 | 12 | **14** | **27** | **17** | **21** | **22** | **17** | **16** | **20** | 19 | 21 | 17 | 13 | 15 | 14 | 14 | 10 | 154 |
| 77 | 4 | 4 | 2 | 2 | 2 | | 4 | 5 | **10** | **11** | **26** | **22** | **19** | **18** | **17** | **15** | 14 | 14 | 15 | 13 | 13 | 10 | 8 | 6 | 138 |
| 82 | | | | | | | | 3 | **4** | **12** | **12** | **19** | **18** | **18** | **17** | **17** | 16 | 16 | 12 | 11 | 8 | 5 | 3 | 4 | 117 |
| 87 | | | | | | | | | **3** | **3** | **9** | **13** | **16** | **16** | **16** | **16** | 13 | 9 | 8 | 9 | 5 | 3 | 2 | | 92 |
| 92 | | | | | | | | | | **1** | **3** | **4** | **9** | **13** | **16** | **14** | 15 | 11 | 10 | 4 | 3 | 1 | | | 60 |
| 97 | | | | | | | | | | | **1** | **4** | **4** | **7** | **8** | **7** | 7 | 9 | 4 | 2 | | | | | 31 |
| 102 | | | | | | | | | | | | | **2** | **3** | **3** | **6** | 6 | 3 | 2 | | | | | | 14 |
| 107 | | | | | | | | | | | | | | | **1** | **1** | 1 | 1 | | | | | | | 2 |
| On Hours | | | | | | | | | 31 | 54 | 68 | 83 | 90 | 92 | 94 | 96 | | | | | | | | | **606.00** |

**Chiller Replacement, EMS, System Optimization (Site 2465)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | High Efficiency Water-Cooled Chillers , EMS, and System Optimization |
| Site Description | College/University |

**Measure Description**

Replace 1 of 2 existing 333-ton chillers with 2 200-ton centrifugal chillers, add an Energy Management System (EMS), add Varibale Frequency Drives (VFDs) on most pumps and fans, reconfigure chilled water piping into primary/secondary piping, replace steam boilers with water boilers, and repair and/or replace dampers to allow for more efficient use of reheat.

**Summary of Ex Ante Impact Calculations**

Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and plant characteristics.

**Comments on PG&E Calculations**

There was not sufficient documentation to verify the energy impact achieved by the measures. There were several changes to the scope of the project that are not reflected in the DOE2.1E output files provided. For example, the results provided are for the installation of screw chillers where centrifugal chillers are actually installed.

**Evaluation Process**

The evaluation process consists of a review of the application form and supporting documentation, conducting an on-site survey and then computing impacts using the on-site data.

The on-site survey was conducted on October 27, 1999 in Oakland (Climate Zone 3). Information on the retrofit equipment and operating conditions was collected through an inspection of the chiller and boiler plant and through an interview with the Chief Engineer.

Due to the lack of site-specific data needed to accurately model the impacts and the discrepancies between claimed and actual retrofit conditions, a detailed model was not built. The errors in the application result in an underestimation of impacts, so slight discrepancies are acceptable. Although ex ante estimates do not reflect exact conditions, there is not sufficient data to accurately replace the ex ante estimate for this site. Therefore, ex ante estimates are accepted as accurate.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| MDSS | 295.9 | 1,034,514.53 | 126,267 |
| Adjusted Engineering | 295.9 | 1,034,514.53 | 126,267 |
| Engineering Realization Rate | 1.0 | 1.0 | 1.0 |

**Boiler Replacement & Economizer Repair (Site 2466)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | Boiler Replacement and Economizer Repair |
| Site Description | College |

**Measure Description**

Install domestic hot water (DHW) heaters at several locations around campus and repair economizers to allow shutdown of boiler plant during summer months.

**Summary of Ex Ante Impact Calculations**

Impacts were developed using DOE2.1E simulation program based on climate zone, building type, boiler plant and DHW usage characteristics.

**Comments on PG&E Calculations**

The results from the DOE2.1E model runs and a portion of the field data collection sheets were provided with the application, so there was not sufficient Ex Ante information to conduct a thorough review of the inputs to the model. The baseline for this project is the pre-retrofit plant.

**Evaluation Process**

The evaluation process consisted of reviewing the application form and supporting documentation and conducting an on-site survey.

The on-site survey was conducted on October 27, 1999 in Oakland (Climate Zone 3). Information on the retrofit equipment and operating conditions were collected through an inspection of the boilers, DHW heaters, and pumps and through an interview with the Chief Engineer. Both pre- and post-retrofit equipment sizes and general scheduling was confirmed during the on-site survey.

Due to the lack of trend data from the EMS, specific operating hours were unobtainable. The Ex Ante impact estimates are accepted as accurate.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 4 | 43,485.97 | 57,491 |
| **Adjusted Engineering** | 4 | 43,485.97 | 57,491 |
| **Engineering Realization Rate** | 1.0 | 1.0 | 1.0 |

**Chiller Replacement (Site 2468)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | High Efficiency Water-Cooled Chiller |
| Site Description | Health Care/Hospital |

**Measure Description**

Replace existing 500-ton chiller with high efficiency 700-ton water-cooled centrifugal chiller with a VSD.

**Summary of Ex Ante Impact Calculations**

Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and chiller characteristics.

**Comments on PG&E Calculations**

The correct climate zone, chiller size category and building characteristics were used in the application calculations. The DOE2 results have the baseline chiller labeled as including a VSD, which decreases the energy use, thereby decreasing the impact. Because the input files or output summaries were not provided, the baseline label was taken to be accurate.

**Evaluation Process**

The evaluation process consists of a review of the application form and supporting documentation, conducting an on-site survey and then computing impacts using the on-site data.

The on-site survey was conducted on October 7, 1999 in Redwood City (Climate Zone 3). Information on the retrofit equipment and operating conditions was collected through an inspection of the chiller and through an interview with the Plant Engineer.

The trend logs from the EMS and the interview provided data for development of a relationship between chiller loading and outdoor dry bulb. The chiller is generally brought online at approximately 55 degrees F and is fully loaded at 100 degrees F outside air temperature. Because this facility is a hospital, cooling may be required at unusual hours and temperatures to serve the operating room.

Models are calibrated with actual weather, EMS setpoints and trends supplied by the contact, observed chiller run hours since the installation, chiller staging strategy supplied by the contact, chilled water temperatures, and condenser water temperatures. Energy impacts are based on typical weather data. A Title 24 baseline, nominal efficiency, and typical year bin weather data for the applicable climate zone are used in the bin analysis. To compute the impacts, the following assumptions were used:

- A baseline Title 24 efficiency of 0.748 kW/ton was used for the 700-ton centrifugal chiller.
- The chiller is brought online at 55 degrees F and reaches full load at 100 degrees F.
- The chiller is available for cooling 8760 hours per year.

Chiller efficiencies at various temperatures were calculated from updated default performance coefficients provided in a memo to the California Energy Commission titled "1995 Proposed Changes to the ACM Manual Central Plant Cooling Equipment" by Mark Hydeman. These coefficients were used to develop a chiller efficiency curve for the Rebate case and a Title 24 base case. Evaluation-based energy impacts were lower and demand impacts were higher than Ex Ante estimates. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 93 | 1,244,758.04 | 0 |
| **Adjusted Engineering** | 122.58 | 487,738.86 | 0 |
| **Engineering Realization Rate** | 1.32 | 0.39 | N/A |

Site 2468: Results

| | Energy | | Demand |
|---|---|---|---|
| | Savings | Impact | Impact |
| MDSS | | 1,244,758 | 93 |
| QC | 491,701 | 487,739 | 123 |
| Realization Rate | | 0.39 | 1.32 |

| Post-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.524 |
| Nom. Tons | 700 |
| nom kw | 366.8 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 102 | 0.00 | 700 | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 |
| 97 | 0.00 | 630 | 0.38 | 0.00 | 0.00 | 2.00 | 484.79 |
| 92 | 1.00 | 560 | 0.36 | 203.59 | 203.59 | 29.00 | 5,904.02 |
| 87 | 28.00 | 490 | 0.34 | 4,673.81 | 166.92 | 59.00 | 9,848.38 |
| 82 | 58.00 | 420 | 0.32 | 7,752.54 | 133.66 | 96.00 | 12,831.79 |
| 77 | 175.00 | 350 | 0.30 | 18,254.58 | 104.31 | 196.00 | 20,445.13 |
| 72 | 408.00 | 280 | 0.28 | 32,065.19 | 78.59 | 523.00 | 41,103.17 |
| 67 | 774.00 | 210 | 0.27 | 43,228.79 | 55.85 | 836.00 | 46,691.56 |
| 62 | 1457.00 | 140 | 0.26 | 52,183.08 | 35.82 | 1,461.00 | 52,326.34 |
| 57 | 2461.00 | 70 | 0.33 | 56,895.35 | 23.12 | 2,186.00 | 50,537.68 |
| Totals | 5,362.00 | | | 215,256.93 | 203.59 | 5,388.00 | 240,172.87 |

| Title 24 Baseline Chiller | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 700 |
| nom kw | 523.660 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 102 | 0.00 | 700 | 0.57 | 0.00 | 0.00 |
| 97 | 0.00 | 630 | 0.58 | 0.00 | 0.00 |
| 92 | 1.00 | 560 | 0.58 | 326.17 | 326.17 |
| 87 | 28.00 | 490 | 0.59 | 8,128.69 | 290.31 |
| 82 | 58.00 | 420 | 0.61 | 14,824.84 | 255.60 |
| 77 | 175.00 | 350 | 0.63 | 38,870.69 | 222.12 |
| 72 | 408.00 | 280 | 0.68 | 77,496.25 | 189.94 |
| 67 | 774.00 | 210 | 0.76 | 123,180.73 | 159.15 |
| 62 | 1457.00 | 140 | 0.93 | 189,135.80 | 129.81 |
| 57 | 2461.00 | 70 | 1.46 | 251,032.62 | 102.00 |
| Totals | 5,362.00 | | | 702,995.79 | 326.17 |

| Pre-Retrofit Chiller | |
|---|---|
| Nom. Eff | 1 |
| Nom. Tons | 500 |
| nom kw | 500 |

| Outdoor DB Temperature (F) | Operating Hours per year (Actual) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 102 | 0.00 | 500 | 0.77 | 0.00 | 0.00 |
| 97 | 2.00 | 450 | 0.77 | 693.35 | 346.68 |
| 92 | 29.00 | 400 | 0.78 | 9,031.44 | 311.43 |
| 87 | 59.00 | 350 | 0.79 | 16,354.43 | 277.19 |
| 82 | 96.00 | 300 | 0.81 | 23,429.03 | 244.05 |
| 77 | 196.00 | 250 | 0.85 | 41,568.20 | 212.08 |
| 72 | 523.00 | 200 | 0.91 | 94,851.27 | 181.36 |
| 67 | 836.00 | 150 | 1.01 | 127,036.66 | 151.96 |
| 62 | 1,461.00 | 100 | 1.24 | 181,086.20 | 123.95 |
| 57 | 2,186.00 | 50 | 1.95 | 212,906.86 | 97.40 |
| Totals | 5388.00 | | | 706,957.45 | 346.68 |

Site 2468: Inputs to Model

| Parameter | Value Reported | Units of Parameter | Notes |
|---|---|---|---|
| City | Redwood City | | |
| Climate Zone | 3 | Belmont | |
| Pre-Retrofit Nominal Chiller Capacity | 500 | Tons | Application |
| Pre-Retrofit Nominal Chiller Efficiency | 1 | kW/ton | Fix This!!!!!! |
| | | | |
| Post-Retrofit Nominal Chiller Capacity | 700 | Tons | Application |
| Post-Retrofit Nominal Chiller Efficiency | 0.524 | kW/ton | From Chiller Rating Sheet |
| Post-Retrofit Full Load Amps | 503 | Amps | York Manual |
| Post-Retrofit Nominal Voltage | 480 | Volts | Contact provided value |
| Baseline Chiller Efficiency | 0.748 | kW/ton | Title 24 Nominal Efficiency for Chiller > 300 Tons |
| | | | |
| On-Site Recorded Operating Voltage | 430 | Volts | York Control Panel |
| On-Site Recorded Operating Amperage | 372.22 | Amps | York Control Panel |
| Operating Power Use | 277.22 | kW | Calculated |
| | | | |
| | | | |
| Chiller AM Lockout | 0:00 | AM | 24/7 Availability |
| Chiller PM Lockout | 0:00 | PM | 24/7 Availability |
| Chiller Startup OSA Temperature | | F | Contact provided estimate |
| Chiller Max Load OSA Temperature | 100 | F | Contact provided estimate |
| Chilled Water Supply Temperature Setpoint | 55 | F | Contact provided setpoints; Chiller is on Manual Operation |
| Condenser Water Temperature | 80 | F | Contact provided setpoints; Chiller is on Manual Operation |
| Date of Chiller Installation | 8/10/98 | | Contact provided estimate |
| Date at Run Hour Reading | 10/7/99 | | Chiller Log |
| Number of Days Chiller Operated | 423 | days | = Read Date - Install Date |
| Run Hours for New Chiller | 6521 | hours | Documented from Chiller Log |
| Average Hours per Year of Chiller Operation | 5626.87 | (M-F Only) | = (Run Hours for New Chiller / Number of Days Chiller Operated) * 365 Days/Year |
| | | | |
| Predicted Run Hours Since Install Using Actual Weather & Setpoints | 6791.00 | hours | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |
| Predicted Hours per Year Using Actual Weather Data & Setpoints | 5388.00 | Hours/Year | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |

Site 2468: Post-Retrofit Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| 3 | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.524 |
| Nom. Tons | 700 |
| nom kw | 366.8 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | | VSD Correction | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton | Scaling Ratio | Corrected kW/ton for VSD |
| 102 | 700 | 80.0 | 55.0 | 704 | 1.000 | 1.00 | 0.77 | 0.1141 | 8.76 | 0.401 | 1.05 | 0.421 |
| 97 | 630 | 79.1 | 53.7 | 711 | 0.900 | 0.89 | 0.78 | 0.1148 | 8.71 | 0.404 | 0.95 | 0.385 |
| 92 | 560 | 78.2 | 52.3 | 716 | 0.800 | 0.79 | 0.78 | 0.1160 | 8.62 | 0.408 | 0.89 | 0.364 |
| 87 | 490 | 77.3 | 51.0 | 720 | 0.700 | 0.70 | 0.79 | 0.1180 | 8.47 | 0.415 | 0.82 | 0.341 |
| 82 | 420 | 76.4 | 49.7 | 722 | 0.600 | 0.61 | 0.80 | 0.1212 | 8.25 | 0.426 | 0.75 | 0.318 |
| 77 | 350 | 75.6 | 48.3 | 724 | 0.500 | 0.52 | 0.81 | 0.1264 | 7.91 | 0.445 | 0.67 | 0.298 |
| 72 | 280 | 74.7 | 47.0 | 724 | 0.400 | 0.44 | 0.82 | 0.1351 | 7.40 | 0.475 | 0.59 | 0.281 |
| 67 | 210 | 73.8 | 45.7 | 722 | 0.300 | 0.37 | 0.82 | 0.1510 | 6.62 | 0.531 | 0.50 | 0.266 |
| 62 | 140 | 72.9 | 44.3 | 720 | 0.200 | 0.30 | 0.83 | 0.1847 | 5.41 | 0.649 | 0.39 | 0.256 |
| 57 | 70 | 72.0 | 43.0 | 716 | 0.100 | 0.23 | 0.84 | 0.2903 | 3.44 | 1.021 | 0.32 | 0.330 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2468: Baseline Chiller

| | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Centrifugal Chiller (Water-Source) | | | | | | |
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| 3 | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 700 |
| nom kw | 523.659574 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | | VSD Correction | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton | Scaling Ratio | Corrected kW/ton for VSD |
| 102 | 700 | 80.0 | 55.0 | 704 | 1.000 | 1.00 | 0.77 | 0.1629 | 6.14 | 0.573 | 1.05 | 0.602 |
| 97 | 630 | 79.1 | 53.7 | 711 | 0.900 | 0.89 | 0.78 | 0.1639 | 6.10 | 0.576 | 0.95 | 0.549 |
| 92 | 560 | 78.2 | 52.3 | 716 | 0.800 | 0.79 | 0.78 | 0.1657 | 6.04 | 0.582 | 0.89 | 0.519 |
| 87 | 490 | 77.3 | 51.0 | 720 | 0.700 | 0.70 | 0.79 | 0.1685 | 5.93 | 0.592 | 0.82 | 0.486 |
| 82 | 420 | 76.4 | 49.7 | 722 | 0.600 | 0.61 | 0.80 | 0.1731 | 5.78 | 0.609 | 0.75 | 0.454 |
| 77 | 350 | 75.6 | 48.3 | 724 | 0.500 | 0.52 | 0.81 | 0.1805 | 5.54 | 0.635 | 0.67 | 0.425 |
| 72 | 280 | 74.7 | 47.0 | 724 | 0.400 | 0.44 | 0.82 | 0.1929 | 5.18 | 0.678 | 0.59 | 0.401 |
| 67 | 210 | 73.8 | 45.7 | 722 | 0.300 | 0.37 | 0.82 | 0.2155 | 4.64 | 0.758 | 0.50 | 0.380 |
| 62 | 140 | 72.9 | 44.3 | 720 | 0.200 | 0.30 | 0.83 | 0.2637 | 3.79 | 0.927 | 0.39 | 0.365 |
| 57 | 70 | 72.0 | 43.0 | 716 | 0.100 | 0.23 | 0.84 | 0.4145 | 2.41 | 1.457 | 0.32 | 0.472 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2468: Pre-Retrofit Chiller

| | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Centrifugal Chiller (Water-Source) | | | | | | |
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| 3 | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 1 |
| Nom. Tons | 500 |
| nom kw | 500 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | | VSD Correction | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton | Scaling Ratio | Corrected kW/ton for VSD |
| 102 | 500 | 80.0 | 55.0 | 503 | 1.000 | 1.00 | 0.77 | 0.2178 | 4.59 | 0.766 | 1.05 | 0.804 |
| 97 | 450 | 79.1 | 53.7 | 508 | 0.900 | 0.89 | 0.78 | 0.2191 | 4.56 | 0.770 | 0.95 | 0.734 |
| 92 | 400 | 78.2 | 52.3 | 511 | 0.800 | 0.79 | 0.78 | 0.2214 | 4.52 | 0.779 | 0.89 | 0.694 |
| 87 | 350 | 77.3 | 51.0 | 514 | 0.700 | 0.70 | 0.79 | 0.2253 | 4.44 | 0.792 | 0.82 | 0.650 |
| 82 | 300 | 76.4 | 49.7 | 516 | 0.600 | 0.61 | 0.80 | 0.2314 | 4.32 | 0.814 | 0.75 | 0.607 |
| 77 | 250 | 75.6 | 48.3 | 517 | 0.500 | 0.52 | 0.81 | 0.2413 | 4.14 | 0.848 | 0.67 | 0.569 |
| 72 | 200 | 74.7 | 47.0 | 517 | 0.400 | 0.44 | 0.82 | 0.2579 | 3.88 | 0.907 | 0.59 | 0.536 |
| 67 | 150 | 73.8 | 45.7 | 516 | 0.300 | 0.37 | 0.82 | 0.2881 | 3.47 | 1.013 | 0.50 | 0.508 |
| 62 | 100 | 72.9 | 44.3 | 514 | 0.200 | 0.30 | 0.83 | 0.3525 | 2.84 | 1.239 | 0.39 | 0.488 |
| 57 | 50 | 72.0 | 43.0 | 511 | 0.100 | 0.23 | 0.84 | 0.5540 | 1.80 | 1.948 | 0.32 | 0.630 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2468: Weather Data

TMY temperature data for climate zone 3

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 3 | | 1 | 4 | 1 | | 1 | | | | | | | | | | | | | | | | | | |
| 37 | 6 | 9 | 13 | 13 | 16 | 15 | 18 | 2 | 1 | | | | | | | | | | | | | 3 | 5 | 6 | |
| 42 | 28 | 31 | 34 | 46 | 45 | 44 | 38 | 28 | 12 | 5 | 1 | | | 1 | 1 | 1 | 1 | 2 | 5 | 6 | 7 | 16 | 21 | 26 | |
| 47 | 72 | 77 | 79 | 84 | 71 | 66 | 70 | 65 | 43 | 31 | 12 | 8 | 6 | 3 | 2 | 2 | 2 | 6 | 21 | 32 | 44 | 43 | 48 | 54 | |
| 52 | 120 | 125 | 125 | 116 | 127 | 122 | 104 | 85 | 79 | 68 | 60 | 43 | 26 | 20 | 17 | 21 | 36 | 53 | 68 | 78 | 93 | 107 | 124 | 127 | |
| 57 | 116 | 105 | 100 | 90 | 95 | 106 | 112 | 120 | 104 | 89 | 83 | 79 | 68 | 70 | 80 | 79 | 95 | 108 | 115 | 129 | 129 | 137 | 127 | 125 | 2461 |
| 62 | 21 | 17 | 12 | 11 | 9 | 11 | 19 | 58 | 98 | 102 | 91 | 77 | 77 | 83 | 79 | 84 | 91 | 111 | 109 | 99 | 83 | 55 | 35 | 25 | 1457 |
| 67 | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 5 | 20 | 56 | 74 | 77 | 72 | 78 | 84 | 78 | 83 | 60 | 38 | 19 | 9 | 4 | 5 | 2 | 774 |
| 72 | | | | | | | | 2 | 7 | 9 | 32 | 51 | 64 | 61 | 58 | 57 | 37 | 19 | 9 | 2 | | | | | 408 |
| 77 | | | | | | | | | 1 | 5 | 10 | 21 | 31 | 30 | 28 | 28 | 15 | 6 | | | | | | | 175 |
| 82 | | | | | | | | | | | 2 | 8 | 13 | 11 | 11 | 9 | 4 | | | | | | | | 58 |
| 87 | | | | | | | | | | | | 1 | 8 | 7 | 5 | 6 | 1 | | | | | | | | 28 |
| 92 | | | | | | | | | | | | | | 1 | | | | | | | | | | | 1 |
| 97 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| 102 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| On Hours | 139 | 123 | 113 | 102 | 105 | 118 | 134 | 185 | 230 | 261 | 292 | 314 | 333 | 341 | 345 | 341 | 326 | 304 | 271 | 249 | 221 | 196 | 167 | 152 | 5362.00 |

Actual temperature by hour from 10/08/98 to 10/07/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | | | | | | | | | | | | | | 1 | 2 | 3 | |
| 37 | 3 | 4 | 8 | 8 | 10 | 12 | 13 | 8 | 5 | 1 | | | | | | | | 1 | 2 | 3 | 4 | 4 | 3 | 3 | |
| 42 | 34 | 36 | 36 | 44 | 45 | 49 | 39 | 32 | 14 | 7 | 4 | 4 | 2 | 2 | 2 | 2 | 2 | 4 | 7 | 8 | 13 | 16 | 23 | 28 | |
| 47 | 66 | 69 | 75 | 69 | 69 | 60 | 52 | 40 | 38 | 29 | 20 | 9 | 9 | 7 | 7 | 8 | 12 | 20 | 33 | 51 | 55 | 60 | 64 | 63 | |
| 52 | 103 | 104 | 99 | 105 | 108 | 90 | 83 | 68 | 62 | 49 | 46 | 42 | 32 | 32 | 33 | 36 | 51 | 75 | 93 | 96 | 98 | 101 | 94 | 98 | |
| 57 | 113 | 107 | 105 | 100 | 97 | 105 | 90 | 80 | 67 | 77 | 74 | 65 | 65 | 69 | 76 | 84 | 93 | 92 | 87 | 100 | 104 | 111 | 112 | 113 | 2186 |
| 62 | 35 | 36 | 33 | 30 | 27 | 40 | 66 | 92 | 92 | 75 | 62 | 69 | 71 | 67 | 69 | 70 | 68 | 83 | 91 | 70 | 65 | 53 | 51 | 46 | 1461 |
| 67 | 6 | 4 | 4 | 3 | 3 | 4 | 14 | 27 | 60 | 83 | 85 | 72 | 63 | 54 | 62 | 71 | 74 | 44 | 29 | 23 | 16 | 13 | 13 | 9 | 836 |
| 72 | 1 | 1 | | 1 | 1 | | 3 | 12 | 16 | 31 | 49 | 66 | 75 | 76 | 59 | 48 | 25 | 20 | 10 | 10 | 8 | 6 | 3 | 2 | 523 |
| 77 | | | | | | | | 1 | 10 | 6 | 13 | 20 | 24 | 30 | 27 | 18 | 19 | 13 | 9 | 4 | 2 | | | | 196 |
| 82 | | | | | | | | | 1 | 7 | 9 | 7 | 13 | 13 | 14 | 12 | 8 | 9 | 3 | | | | | | 96 |
| 87 | | | | | | | | | | | 3 | 10 | 7 | 11 | 6 | 9 | 8 | 4 | 1 | | | | | | 59 |
| 92 | | | | | | | | | | | | 1 | 4 | 4 | 9 | 6 | 5 | | | | | | | | 29 |
| 97 | | | | | | | | | | | | | | | 1 | 1 | | | | | | | | | 2 |
| 102 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| On Hours | 155 | 148 | 142 | 134 | 128 | 149 | 173 | 212 | 246 | 279 | 295 | 310 | 322 | 324 | 323 | 319 | 300 | 265 | 230 | 207 | 195 | 183 | 179 | 170 | 5388.00 |

Actual temperature by hour from 08/10/98 to 10/07/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | | | | | | | | | | | | | | 1 | 2 | 3 | |
| 37 | 3 | 4 | 8 | 8 | 10 | 12 | 13 | 8 | 5 | 1 | | | | | | | | 1 | 2 | 3 | 4 | 4 | 3 | 3 | |
| 42 | 34 | 36 | 36 | 44 | 45 | 49 | 39 | 32 | 14 | 7 | 4 | 4 | 2 | 2 | 2 | 2 | 2 | 4 | 7 | 8 | 13 | 16 | 23 | 28 | |
| 47 | 66 | 69 | 75 | 69 | 69 | 60 | 52 | 40 | 38 | 29 | 20 | 9 | 9 | 7 | 7 | 8 | 12 | 20 | 33 | 51 | 55 | 60 | 64 | 63 | |
| 52 | 104 | 105 | 101 | 107 | 112 | 93 | 83 | 68 | 62 | 49 | 46 | 42 | 32 | 32 | 33 | 36 | 51 | 75 | 93 | 96 | 98 | 101 | 94 | 98 | |
| 57 | 146 | 144 | 143 | 139 | 134 | 141 | 110 | 87 | 69 | 77 | 74 | 65 | 65 | 69 | 76 | 84 | 93 | 94 | 96 | 112 | 114 | 121 | 130 | 133 | 2516 |
| 62 | 50 | 50 | 48 | 44 | 42 | 57 | 94 | 122 | 113 | 84 | 68 | 73 | 75 | 69 | 73 | 78 | 83 | 100 | 111 | 91 | 96 | 89 | 81 | 74 | 1865 |
| 67 | 14 | 9 | 7 | 6 | 6 | 7 | 23 | 43 | 82 | 107 | 106 | 88 | 73 | 66 | 75 | 85 | 85 | 59 | 42 | 41 | 27 | 20 | 22 | 18 | 1111 |
| 72 | 3 | 3 | 1 | 2 | 1 | | 5 | 16 | 27 | 49 | 65 | 82 | 91 | 89 | 70 | 55 | 36 | 30 | 20 | 14 | 15 | 12 | 5 | 4 | 695 |
| 77 | | | | | | | | 3 | 12 | 12 | 23 | 34 | 40 | 44 | 39 | 34 | 33 | 23 | 15 | 8 | 2 | | | | 322 |
| 82 | | | | | | | | | 2 | 9 | 14 | 12 | 19 | 23 | 25 | 18 | 12 | 13 | 4 | | | | | | 151 |
| 87 | | | | | | | | | | | 4 | 14 | 14 | 19 | 11 | 15 | 12 | 5 | 1 | | | | | | 95 |
| 92 | | | | | | | | | | | | 1 | 4 | 4 | 12 | 8 | 5 | | | | | | | | 34 |
| 97 | | | | | | | | | | | | | | | 1 | 1 | | | | | | | | | 2 |
| 102 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| On Hours | 213 | 206 | 199 | 191 | 183 | 205 | 232 | 271 | 305 | 338 | 354 | 369 | 381 | 383 | 382 | 378 | 359 | 324 | 289 | 266 | 254 | 242 | 238 | 229 | 6791.00 |

**Installation of EMS (Site 2475 & 2476)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | Installation of Energy Management System |
| Site Description | Personal Service |

**Measure Description** Install a fully integrated DDC system to control the HVAC and lighting equipment in three-building complex.

**Summary of Ex Ante Impact Calculations** Ex ante calculations were performed using a spreadsheet program to estimate demand and energy impacts.

**Comments on PG&E Calculations** The application calculations used the correct algorithms to estimate energy and demand impacts.

**Evaluation Process** The evaluation process consists of a review of the application form and supporting documentation. The contact at the site was unwilling to provide access to the site in order to gather the necessary information to conduct ex post engineering estimates. After a thorough review of the application and replication of several of the impact calculations, ex ante estimates are accepted as accurate.

**Additional Notes**

**Impact Results**

| 2475 | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 0 | 219,176.15 | 0 |
| **Adjusted Engineering** | 0 | 219,176.15 | 0 |
| **Engineering Realization Rate** | N/A | 1.00 | N/A |

| 2476 | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 0 | 1,064,708.06 | 0 |
| **Adjusted Engineering** | 0 | 1,064,708.06 | 0 |
| **Engineering Realization Rate** | N/A | 1.00 | N/A |

**Chiller Replacement (Site 2482)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | High Efficiency Water-Cooled Chiller |
| Site Description | Health Care/Hospital |

**Measure Description** Replace existing 177-ton compressors for Thermal Energy Storage system and 210-ton chiller with two 300-ton high-efficiency water-cooled chillers.

**Summary of Ex Ante Impact Calculations** Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and chiller characteristics.

**Comments on PG&E Calculations** The correct climate zone, chiller size category and building characteristics were used in the application calculations. However, the calibration to customer billing records appears to have over-estimated the chiller contribution to those bills, resulting in a considerable over-estimation of impact. The most likely source of error is the hours of operation for the chillers.

**Evaluation Process** The evaluation process consists of a review of the application form and supporting documentation, conducting an on-site survey and then computing impacts using the on-site data. Models are calibrated with actual weather, observed chiller run hours since the installation, chiller loading under extreme outdoor temperature conditions, chilled water temperature, and condenser water temperature. Energy impacts are based on typical weather data. A Title 24 baseline, nominal efficiency, and typical year bin weather data for the applicable climate zone are used in the bin analysis.

The on-site survey was conducted on August 10, 1999 in Clovis (Climate Zone 13). Information on the retrofit equipment and operating conditions was collected through an inspection of the chillers and through an interview with the Service Coordinator.

Discussions provided data for development of a relationship between chiller loading and outdoor dry bulb. The two chillers, chiller #2 and chiller #3, are operated in a lead/lag configuration. Once the lag chiller is brought on line, the two chillers split the load evenly. The chillers are alternated between lead and lag approximately once per month. The chillers are available 24 hours per day, 7 days per week. The lead chiller is brought on line at 62 degrees outside air temperature. The lag chiller is brought on line to split the load at 85 degrees outside air temperature. The Service Coordinator estimated that the chillers reaches 100% loading at approximately 115 degrees outside air temperature. Chiller #1, the original chiller, operates only once per month for exercise.

To compute the impacts, the following assumptions were used:

- At the time of the audit chiller #3 was designated as the lead chiller and chiller #2 was designated as the lag chiller.

- A linear loading strategy was used for the analysis of both the baseline, and rebated chillers, which assumed initial loading of chiller #3 at 62 degrees and 100% loading at 85 Degrees F. At this point, chiller #2 comes on line, and both chillers split the load equally until they both reach 100%. Both chillers have not reached 100% loading yet.

- Based on a water-cooled chiller greater than 300 tons, a baseline Title 24 efficiency of 0.748 KW/ton was used.

Chiller efficiencies at various temperatures were calculated from updated default performance coefficients provided in a memo to the California Energy Commission titled "1995 Proposed Changes to the ACM Manual Central Plant Cooling Equipment" by Mark Hydeman. These coefficients were used to develop a chiller efficiency curve for the Rebate case and a Title 24 base case. Both evaluation-based demand and energy impacts were lower than Ex Ante estimates. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 99 | 485,735.99 | 0 |
| **Adjusted Engineering** | 77.51 | 132,540.79 | 0 |
| **Engineering Realization Rate** | 0.78 | 0.27 | N/A |

Site 2482: Results

| Impacts | Energy | Demand |
|---|---|---|
| MDSS | 485,736 | 99 |
| QC | 132,541 | 78 |
| Realization Rate | 0.27 | 0.78 |

| Title 24 Baseline Chiller #2 | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 235 |
| nom kw | 175.780 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 112 | 0.00 | 235 | 0.62 | 0.00 | 144.56 |
| 107 | 5.00 | 212 | 0.61 | 649.18 | 129.84 |
| 102 | 96.00 | 188 | 0.62 | 11,108.28 | 115.71 |
| 97 | 216.00 | 165 | 0.62 | 22,074.05 | 102.19 |
| 92 | 345.00 | 141 | 0.63 | 30,807.18 | 89.30 |
| 87 | 418.00 | 118 | 0.66 | 32,196.59 | 77.03 |
| Totals | 1,080.00 | | | 96,835.28 | 144.56 |

| Post-Retrofit Chiller #2 | |
|---|---|
| Nom. Eff | 0.557 |
| Nom. Tons | 235 |
| nom kw | 130.895 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 112 | 0.00 | 235 | 0.46 | 0.00 | 107.65 | 0.00 | 0.00 |
| 107 | 5.00 | 212 | 0.46 | 483.41 | 96.68 | 35.00 | 3,383.89 |
| 102 | 96.00 | 188 | 0.46 | 8,271.81 | 86.16 | 113.00 | 9,736.61 |
| 97 | 216.00 | 165 | 0.46 | 16,437.49 | 76.10 | 226.00 | 17,198.49 |
| 92 | 345.00 | 141 | 0.47 | 22,940.64 | 66.49 | 373.00 | 24,802.49 |
| 87 | 418.00 | 118 | 0.49 | 23,975.27 | 57.36 | 437.00 | 25,065.06 |
| Totals | 1,080.00 | | | 72,108.63 | 107.65 | 1,184.00 | 80,186.53 |

| Title 24 Baseline Chiller #3 | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 235 |
| nom kw | 175.780 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 112 | 0.00 | 235 | 0.62 | 0.00 | 144.56 |
| 107 | 5.00 | 212 | 0.61 | 649.18 | 129.84 |
| 102 | 96.00 | 188 | 0.62 | 11,108.28 | 115.71 |
| 97 | 216.00 | 165 | 0.62 | 22,074.05 | 102.19 |
| 92 | 345.00 | 141 | 0.63 | 30,807.18 | 89.30 |
| 87 | 418.00 | 118 | 0.66 | 32,196.59 | 77.03 |
| 82 | 544.00 | 235 | 0.68 | 86,497.30 | 159.00 |
| 77 | 606.00 | 188 | 0.66 | 74,876.18 | 123.56 |
| 72 | 722.00 | 141 | 0.66 | 66,865.15 | 92.61 |
| 67 | 842.00 | 94 | 0.70 | 55,487.98 | 65.90 |
| 62 | 965.00 | 47 | 0.92 | 41,663.09 | 43.17 |
| Totals | 4,759.00 | | | 422,224.98 | 159.00 |

| Post-Retrofit Chiller #3 | |
|---|---|
| Nom. Eff | 0.557 |
| Nom. Tons | 235 |
| nom kw | 130.895 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 112 | 0.00 | 235 | 0.46 | 0.00 | 107.65 | 0.00 | 0.00 |
| 107 | 5.00 | 212 | 0.46 | 483.41 | 96.68 | 35.00 | 3,383.89 |
| 102 | 96.00 | 188 | 0.46 | 8,271.81 | 86.16 | 113.00 | 9,736.61 |
| 97 | 216.00 | 165 | 0.46 | 16,437.49 | 76.10 | 226.00 | 17,198.49 |
| 92 | 345.00 | 141 | 0.47 | 22,940.64 | 66.49 | 373.00 | 24,802.49 |
| 87 | 418.00 | 118 | 0.49 | 23,975.27 | 57.36 | 437.00 | 25,065.06 |
| 82 | 544.00 | 235 | 0.50 | 64,410.42 | 118.40 | 551.00 | 65,239.23 |
| 77 | 606.00 | 188 | 0.49 | 55,756.73 | 92.01 | 4,139.00 | 380,820.31 |
| 72 | 722.00 | 141 | 0.49 | 49,791.30 | 68.96 | 672.00 | 46,343.15 |
| 67 | 842.00 | 94 | 0.52 | 41,319.25 | 49.07 | 813.00 | 39,896.14 |
| 62 | 965.00 | 47 | 0.68 | 31,024.52 | 32.15 | 884.00 | 28,420.39 |
| Totals | 4,759.00 | | | 314,410.85 | 118.40 | 8,243.00 | 640,905.75 |

Site 2482: Inputs to Model

| Parameter | Value Reported | Units of Parameter | Notes |
|---|---|---|---|
| Pre-Retrofit Chiller #1 Nominal Capacity | 210 | Tons | Application |
| Pre-Retrofit Chiller #1 Nominal Efficiency | 0.76 | kW/ton | Application |
| Post-Retrofit Chiller #1 Nominal Capacity | 210 | Tons | Same as Pre-Retrofit; Chiller Used for Emergency Backup Only |
| Post-Retrofit Chiller #1 Nominal Efficiency | 0.76 | kW/ton | Same as Pre-Retrofit; Chiller Used for Emergency Backup Only |
| | | | |
| Pre-Retrofit Chiller #2 Nominal Capacity | 88.5 | Tons | Application |
| Pre-Retrofit Chiller #2 Nominal Efficiency | 0.82 | kW/ton | Application |
| Post-Retrofit Chiller #2 Nominal Capacity | 235 | Tons | Application |
| Post-Retrofit Chiller #2 Nominal Efficiency | 0.557 | kW/ton | From Chiller Rating Sheet |
| Post-Retrofit Chiller #2 Full Load Amps | 236 | FLA | From York Manual |
| Post-Retrofit Chiller #2 Startup OSA Temperature | 85 | F | Contact provided estimate |
| Post-Retrofit Chiller #2 Max Load OSA Temperature | ? | F | Contact provided estimate |
| Post-Retrofit Chiller #2 Chilled Water Supply Temperature Setpoint | 48 | F | Contact provided setpoints |
| Post-Retrofit Chiller #2 Condenser Water Temperature Setpoint | 74.55 | F | Contact provided setpoints |
| | | | |
| Pre-Retrofit Chiller #3 Nominal Capacity | 88.5 | Tons | Application |
| Pre-Retrofit Chiller #3 Nominal Efficiency | 0.82 | kW/ton | Application |
| Post-Retrofit Chiller #3 Nominal Capacity | 235 | Tons | Application |
| Post-Retrofit Chiller #3 Nominal Efficiency | 0.557 | kW/ton | From Chiller Rating Sheet |
| Post-Retrofit Chiller #3 Full Load Amps | 236 | FLA | From York Manual |
| Post-Retrofit Chiller #3 Startup OSA Temperature | 62 | F | Contact provided estimate |
| Post-Retrofit Chiller #3 Max Load OSA Temperature | ? | F | Contact provided estimate |
| Post-Retrofit Chiller #3 Chilled Water Supply Temperature Setpoint | 45 | F | Contact provided setpoints |
| Post-Retrofit Chiller #3 Condenser Water Temperature Setpoint | 72.5 | F | Contact provided setpoints |
| Baseline Chiller Efficiency | 0.748 | kW/ton | Title 24 Nominal Efficiency for Chiller > 300 Tons |
| | | | |
| Chiller AM Lockout | 0:00 | AM | 24 hours per day, 7 days per week |
| Chiller PM Lockout | 0:00 | PM | 24 hours per day, 7 days per week |
| Post-Retrofit Chiller #2 Run Hours | 3931 | hours | Documented from Chiller Log |
| Post-Retrofit Chiller #3 Run Hours | 3820 | hours | Documented from Chiller Log |
| Total Post-Retrofit Chiller Run Hours | 7751 | hours | = Chiller #2 Run Hours + Chiller #3 Run Hours |
| Date of Chiller Installation | 3/15/98 | | Contact provided estimate |
| Date at Run Hour Reading | 8/10/99 | | |
| Number of Days Chillers Operated | 514 | days | = ((Read Date - Install Date) * 5/7) - 10 Holidays |
| Average Hours per Year of Operation for Chiller #2 | 2791.47 | Hours/Year | = (Run Hours for New Chiller / Number of Days Chiller Operated) * 365 Days/Year |
| Average Hours per Year of Operation for Chiller #3 | 2712.65 | Hours/Year | = (Run Hours for New Chiller / Number of Days Chiller Operated) * 365 Days/Year |
| Average Hours per Year of Operation for Both Chillers | 5504.11 | Hours/Year | = Chiller #2 Average Hours per Year + Chiller #3 Average Hours per Year |
| Chiller #2 Run Hours Since Install Using Actual Weather & Setpoints | 1887.00 | hours | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |
| Chiller #3 Run Hours Since Install Using Actual Weather & Setpoints | 7445.00 | hours | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |
| Total Modeled Post-Retrofit Chiller Run Hours | 9332.00 | hours | = Chiller #2 Modeled Run Hours + Chiller #3 Modeled Run Hours |
| Chiller #2 Modeled Hours per Year from Actual Weather Data | 1184.00 | Hours/Year | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |
| Chiller #3 Modeled Hours per Year from Actual Weather Data | 4754.00 | Hours/Year | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |
| Total Modeled Post-Retrofit Hours per Year | 5938.00 | Hours/Year | = Chiller #2 Modeled Hours per Year + Chiller #3 Modeled Hours per Year |

Site 2482: Post-Retrofit Chiller #2

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.557 |
| Nom. Tons | 235 |
| nom kw | 130.895 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 235 | 83.5 | 54 | 236 | 1.000 | 1.00 | 0.82 | 0.1303 | 7.68 | 0.458 |
| 107 | 212 | 82.5 | 53 | 238 | 0.900 | 0.89 | 0.83 | 0.1300 | 7.69 | 0.457 |
| 102 | 188 | 81.5 | 52 | 239 | 0.800 | 0.79 | 0.83 | 0.1304 | 7.67 | 0.458 |
| 97 | 165 | 80.5 | 51 | 240 | 0.700 | 0.70 | 0.83 | 0.1316 | 7.60 | 0.463 |
| 92 | 141 | 79.5 | 50 | 241 | 0.600 | 0.61 | 0.83 | 0.1341 | 7.46 | 0.472 |
| 87 | 118 | 78.5 | 49 | 242 | 0.500 | 0.52 | 0.83 | 0.1388 | 7.20 | 0.488 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2482: Post-Retrofit Chiller #3

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.557 |
| Nom. Tons | 235 |
| nom kw | 130.895 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 235 | 83.5 | 54 | 236 | 1.000 | 1.00 | 0.82 | 0.1303 | 7.68 | 0.458 |
| 107 | 212 | 82.5 | 53 | 238 | 0.900 | 0.89 | 0.83 | 0.1300 | 7.69 | 0.457 |
| 102 | 188 | 81.5 | 52 | 239 | 0.800 | 0.79 | 0.83 | 0.1304 | 7.67 | 0.458 |
| 97 | 165 | 80.5 | 51 | 240 | 0.700 | 0.70 | 0.83 | 0.1316 | 7.60 | 0.463 |
| 92 | 141 | 79.5 | 50 | 241 | 0.600 | 0.61 | 0.83 | 0.1341 | 7.46 | 0.472 |
| 87 | 118 | 78.5 | 49 | 242 | 0.500 | 0.52 | 0.83 | 0.1388 | 7.20 | 0.488 |
| 82 | 235 | 83 | 48 | 236 | 1.000 | 1.00 | 0.91 | 0.1433 | 6.98 | 0.504 |
| 77 | 188 | 80.5 | 47.25 | 238 | 0.800 | 0.79 | 0.89 | 0.1392 | 7.18 | 0.489 |
| 72 | 141 | 78 | 46.5 | 240 | 0.600 | 0.61 | 0.86 | 0.1391 | 7.19 | 0.489 |
| 67 | 94 | 75.5 | 45.75 | 242 | 0.400 | 0.44 | 0.84 | 0.1485 | 6.73 | 0.522 |
| 62 | 47 | 73 | 45 | 242 | 0.200 | 0.30 | 0.82 | 0.1946 | 5.14 | 0.684 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2482: Baseline Chiller #2

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 235 |
| nom kw | 175.78 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 235 | 83.5 | 54 | 236 | 1.000 | 1.00 | 0.82 | 0.1750 | 5.72 | 0.615 |
| 107 | 212 | 82.5 | 53 | 238 | 0.900 | 0.89 | 0.83 | 0.1746 | 5.73 | 0.614 |
| 102 | 188 | 81.5 | 52 | 239 | 0.800 | 0.79 | 0.83 | 0.1751 | 5.71 | 0.615 |
| 97 | 165 | 80.5 | 51 | 240 | 0.700 | 0.70 | 0.83 | 0.1767 | 5.66 | 0.621 |
| 92 | 141 | 79.5 | 50 | 241 | 0.600 | 0.61 | 0.83 | 0.1801 | 5.55 | 0.633 |
| 87 | 118 | 78.5 | 49 | 242 | 0.500 | 0.52 | 0.83 | 0.1864 | 5.36 | 0.656 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2482: Baseline Chiller #3

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 235 |
| nom kw | 175.78 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 235 | 83.5 | 54 | 236 | 1.000 | 1.00 | 0.82 | 0.1750 | 5.72 | 0.615 |
| 107 | 212 | 82.5 | 53 | 238 | 0.900 | 0.89 | 0.83 | 0.1746 | 5.73 | 0.614 |
| 102 | 188 | 81.5 | 52 | 239 | 0.800 | 0.79 | 0.83 | 0.1751 | 5.71 | 0.615 |
| 97 | 165 | 80.5 | 51 | 240 | 0.700 | 0.70 | 0.83 | 0.1767 | 5.66 | 0.621 |
| 92 | 141 | 79.5 | 50 | 241 | 0.600 | 0.61 | 0.83 | 0.1801 | 5.55 | 0.633 |
| 87 | 118 | 78.5 | 49 | 242 | 0.500 | 0.52 | 0.83 | 0.1864 | 5.36 | 0.656 |
| 82 | 235 | 83 | 48 | 236 | 1.000 | 1.00 | 0.91 | 0.1924 | 5.20 | 0.677 |
| 77 | 188 | 80.5 | 47.25 | 238 | 0.800 | 0.79 | 0.89 | 0.1869 | 5.35 | 0.657 |
| 72 | 141 | 78 | 46.5 | 240 | 0.600 | 0.61 | 0.86 | 0.1868 | 5.35 | 0.657 |
| 67 | 94 | 75.5 | 45.75 | 242 | 0.400 | 0.44 | 0.84 | 0.1994 | 5.02 | 0.701 |
| 62 | 47 | 73 | 45 | 242 | 0.200 | 0.30 | 0.82 | 0.2613 | 3.83 | 0.919 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2482: Weather Data

TMY temperature data

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | 1 | 3 | 3 | | | | | | | | | | | | | | | | | | |
| 32 | 4 | 6 | 10 | 14 | 15 | 19 | 19 | 7 | | | | | | | | | | | | | 2 | 4 | 4 | 4 | |
| 37 | 27 | 32 | 34 | 34 | 37 | 32 | 31 | 26 | 17 | 8 | 1 | | | | | | | 2 | 5 | 7 | 6 | 9 | 17 | 26 | |
| 42 | 41 | 40 | 36 | 41 | 37 | 42 | 43 | 34 | 24 | 19 | 13 | 8 | 3 | 3 | 3 | 3 | 5 | 7 | 10 | 19 | 27 | 31 | 32 | 32 | |
| 47 | 50 | 54 | 64 | 65 | 65 | 55 | 48 | 45 | 38 | 24 | 20 | 15 | 11 | 9 | 9 | 8 | 14 | 19 | 29 | 26 | 33 | 42 | 49 | 50 | |
| 52 | 61 | 61 | 61 | 59 | 56 | 53 | 49 | 48 | 49 | 49 | 41 | 35 | 25 | 24 | 21 | 23 | 30 | 45 | 41 | 59 | 58 | 60 | 56 | 55 | |
| 57 | 43 | 42 | 41 | 44 | 48 | 42 | 38 | 39 | 36 | 39 | 46 | 46 | 42 | 41 | 41 | 39 | 42 | 42 | 49 | 43 | 47 | 37 | 44 | 50 | |
| 62 | 35 | 44 | 52 | 63 | 55 | 46 | 39 | 36 | 37 | 35 | 36 | 37 | 39 | 38 | 43 | 37 | 41 | 36 | 40 | 38 | 36 | 40 | 29 | 33 | 965 |
| 67 | 53 | 52 | 40 | 21 | 33 | 47 | 48 | 39 | 37 | 31 | 26 | 27 | 36 | 39 | 31 | 36 | 33 | 32 | 28 | 25 | 22 | 28 | 39 | 39 | 842 |
| 72 | 33 | 26 | 22 | 23 | 17 | 20 | 27 | 41 | 42 | 37 | 33 | 33 | 26 | 23 | 27 | 25 | 24 | 27 | 25 | 32 | 33 | 37 | 47 | 42 | 722 |
| 77 | 15 | 8 | 5 | 1 | 1 | 6 | 18 | 35 | 39 | 41 | 39 | 36 | 29 | 30 | 27 | 26 | 25 | 24 | 32 | 30 | 43 | 42 | 29 | 25 | 606 |
| 82 | 3 | | | 0 | | | 2 | 13 | 33 | 45 | 44 | 35 | 39 | 36 | 35 | 35 | 30 | 35 | 28 | 38 | 39 | 27 | 18 | 9 | 544 |
| 87 | | | | | | | | 2 | 12 | 31 | 38 | 42 | 39 | 31 | 27 | 29 | 36 | 27 | 42 | 36 | 17 | 8 | 1 | | 418 |
| 92 | | | | | | | | | 1 | 6 | 25 | 36 | 37 | 39 | 42 | 43 | 39 | 37 | 26 | 12 | 2 | | | | 345 |
| 97 | | | | | | | | | | | 3 | 15 | 31 | 36 | 36 | 31 | 27 | 27 | 10 | | | | | | 216 |
| 102 | | | | | | | | | | | | | 8 | 15 | 22 | 27 | 19 | 5 | | | | | | | 96 |
| 107 | | | | | | | | | | | | | | 1 | 1 | 3 | | | | | | | | | 5 |
| 112 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| On Hours for Chiller #2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 13 | 37 | 66 | 93 | 115 | 122 | 128 | 133 | 121 | 96 | 78 | 48 | 19 | 8 | 1 | 0 | 1080.00 |
| On Hours for Chiller #3 | 139 | 130 | 119 | 108 | 106 | 119 | 134 | 166 | 201 | 226 | 244 | 261 | 284 | 288 | 291 | 292 | 274 | 250 | 231 | 211 | 192 | 182 | 163 | 148 | 4759.00 |

Note: Total "On Hours" value has been scaled by 5/7 to account for M-F operation only

Actual temperature data for climate zone 13 for 7/24/98 to 7/23/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | . | . | . | 1 | 1 | 1 | 2 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 27 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 1 | 1 | . | . | . | . | . | . | . | . | . | 1 | 1 | 2 | 3 | |
| 32 | 9 | 9 | 15 | 16 | 15 | 19 | 18 | 16 | 12 | 6 | 2 | 3 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 4 | 2 | 5 | 4 | 5 | |
| 37 | 15 | 21 | 17 | 20 | 27 | 30 | 31 | 28 | 21 | 16 | 13 | 9 | 6 | 3 | 3 | 3 | 5 | 7 | 9 | 11 | 14 | 18 | 19 | 17 | |
| 42 | 33 | 37 | 39 | 37 | 40 | 40 | 44 | 29 | 24 | 18 | 11 | 10 | 12 | 11 | 7 | 6 | 9 | 9 | 12 | 13 | 18 | 16 | 23 | 25 | |
| 47 | 49 | 54 | 59 | 57 | 55 | 50 | 44 | 52 | 39 | 31 | 23 | 16 | 12 | 13 | 15 | 17 | 16 | 20 | 23 | 29 | 26 | 35 | 36 | 49 | |
| 52 | 55 | 44 | 43 | 55 | 57 | 60 | 47 | 41 | 48 | 49 | 43 | 34 | 25 | 16 | 18 | 18 | 24 | 26 | 39 | 43 | 56 | 54 | 58 | 56 | |
| 57 | 41 | 51 | 50 | 45 | 45 | 41 | 48 | 38 | 35 | 40 | 47 | 51 | 55 | 48 | 41 | 45 | 43 | 51 | 51 | 46 | 44 | 44 | 40 | 40 | |
| 62 | 40 | 36 | 39 | 41 | 40 | 39 | 34 | 34 | 39 | 27 | 36 | 36 | 32 | 42 | 46 | 41 | 42 | 39 | 29 | 33 | 27 | 31 | 42 | 39 | 884 |
| 67 | 33 | 39 | 39 | 41 | 41 | 42 | 40 | 33 | 30 | 42 | 24 | 29 | 37 | 37 | 35 | 34 | 30 | 26 | 22 | 26 | 32 | 34 | 33 | 34 | 813 |
| 72 | 42 | 34 | 29 | 24 | 20 | 18 | 22 | 39 | 30 | 31 | 39 | 32 | 20 | 18 | 23 | 23 | 19 | 22 | 30 | 30 | 36 | 28 | 27 | 36 | 672 |
| 77 | 19 | 16 | 18 | 15 | 14 | 15 | 21 | 21 | 36 | 27 | 28 | 30 | 36 | 38 | 31 | 26 | 32 | 36 | 30 | 33 | 27 | 31 | 41 | 29 | 650 |
| 82 | 16 | 15 | 11 | 8 | 6 | 6 | 10 | 21 | 25 | 38 | 38 | 32 | 29 | 27 | 27 | 33 | 32 | 26 | 30 | 21 | 30 | 37 | 17 | 16 | 551 |
| 87 | 10 | 6 | 3 | 2 | 1 | 1 | 2 | 8 | 16 | 22 | 28 | 33 | 33 | 30 | 28 | 28 | 24 | 23 | 25 | 41 | 28 | 17 | 14 | 14 | 437 |
| 92 | . | . | . | . | . | . | . | 1 | 7 | 13 | 20 | 26 | 33 | 34 | 34 | 33 | 34 | 39 | 38 | 21 | 16 | 13 | 9 | 2 | 373 |
| 97 | . | . | . | . | . | . | . | . | . | 4 | 10 | 17 | 18 | 25 | 29 | 30 | 31 | 24 | 15 | 14 | 8 | 1 | . | . | 226 |
| 102 | . | . | . | . | . | . | . | . | . | . | 2 | 7 | 15 | 18 | 16 | 15 | 16 | 14 | 10 | . | . | . | . | . | 113 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 3 | 11 | 12 | 7 | 1 | . | . | . | . | . | . | 35 |
| 112 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| On Hours for Chiller #2 | 10 | 6 | 3 | 2 | 1 | 1 | 2 | 9 | 23 | 39 | 60 | 83 | 100 | 110 | 118 | 118 | 112 | 101 | 88 | 76 | 52 | 31 | 23 | 16 | 1184.00 |
| On Hours for Chiller #3 | 160 | 146 | 139 | 131 | 122 | 121 | 129 | 157 | 183 | 204 | 225 | 242 | 254 | 272 | 280 | 275 | 267 | 250 | 229 | 219 | 204 | 192 | 183 | 170 | 4754.00 |

EMS System Upgrade (Site 2488)

| | |
|---|---|
| Program | Advance Performance Options |
| Measure | EMS And HVAC System Control |
| Site Description | Health Care/Hospital |

**Measure Description**

Install a DDC energy management system to reduce the number of operating hours for air handlers, control heating water, chilled water and condenser water temperatures, and occupancy based control of common area air handlers.

**Summary of Ex Ante Impact Calculations**

Impacts were determined using engineering calculations, which represent the demand and energy use of the fans that are controlled by the EMS. The baseline for this site was assumed to be the pre-retrofit conditions. Impacts were based on the reduced number of operating hours of selected air handlers to correspond to occupancy schedules. Electricity is saved by reducing the number of operating hours of the compressors, fans and pumps; as well as reducing the number of hours the buildings are conditioned by reset thermostats during unoccupied periods. Connected loads were based on detailed audits of the facility.

**Comments on Calculations**

Impacts calculations were based on the reduction of operating hours for fans with schedules controlled by the EMS and the corresponding heating and cooling impacts associated with the reduced fan operating hours. Appropriate equipment efficiencies, size, and cfm were used. Operating hours for areas controlled by occupancy sensors were adjusted by either 0.6 or 0.8, but there was no justification of these estimates.

**Evaluation Process**

The evaluation process consisted of reviewing the application form and supporting documentation, conducting an on-site survey and reviewing the results from the spreadsheets accompanying the application.

The on-site survey was conducted on September 28, 1999 in Oakland (Climate Zone 3) with the Director of Maintenance. Pre and post retrofit schedules were reconfirmed through interviews with the Director of Maintenance. Occupancy schedules of some zones have changed since the project was completed.

The engineering calculations used for the analyses were accepted as an accurate representation of pre- and post-retrofit conditions. These same calculations were carried out with the actual occupancy schedules obtained during the on-site audit. For the areas controlled by occupancy sensors, the ex ante occupancy estimates were accepted as accurate.

**Additional Notes**

There are also impacts associated with controlling the temperatures of the chiller, boiler, and condenser water, which were not estimated in the ex ante analysis, and are not developed here. The site has undergone several retrofits that make actual impacts impossible to accurately model. The boiler system was replaced at roughly the same time as the EMS retrofit, and a 100-ton chiller was replaced with a new, 225-ton chiller approximately one year later. There was also a VFD installed on one of the supply fans, which is covered under a separate application.

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 0.0 | 118,304.67 | 9,819 |
| **Adjusted Engineering** | 0.0 | 109,802.87 | 8,544.56 |
| **Engineering Realization Rate** | N/A | 0.93 | 0.87 |

Site 2488: Inputs and Results

Inputs

| Parameter | Value | Units |
|---|---|---|
| Load Factor | 0.63 | - |
| Cooling Degree Days | 420 | Days |
| Chiller Efficiency | 1.3 | kW/ton |
| Heating Degree Days | 2962 | Days |
| Boiler Efficiency | 0.84 | - |

Results

| | Ex Ante | | Ex Post | | Realization Rate | |
|---|---|---|---|---|---|---|
| Fans | kWh | Therms | kWh | Therms | kWh | Therms |
| S1 and E3 | 20,053.56 | 1,146.29 | 24,684.98 | 1,411.03 | 1.23 | 1.23 |
| S2, S3, S6, E4 and E5 | 40,470.21 | 2,174.38 | 38,560.57 | 2,079.17 | 0.95 | 0.96 |
| S4, E7, and E12 | 50,447.22 | 6,498.46 | 39,235.38 | 5,054.36 | 0.78 | 0.78 |
| E9 | 7,321.94 | N/A | 7,321.94 | N/A | 1.00 | N/A |
| Total | 118,304.67 | 9,819.00 | 109,802.87 | 8,544.56 | 0.93 | 0.87 |

Site 2488: Ex Ante Impact Calculations

| Supply and Exhaust Fan Savings | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Post-Retrofit Conditions | | | | | | | | | | |
| Fan | Serves | Pre-Retrofit Hours per Year | Start Time | Stop Time | Hours per Day | Hours per Year | Horsepower | Motor Full Load Efficiency | kW | Pre-Retrofit kWh | Post-Retrofit kWh | kWh Savings |
| S-1 | Lobby, Offices | 8,760 | 6:30 AM | 11:30 PM | 17 | 6,205 | 10 | 0.85 | 5.53 | 48,436 | 34,309 | 14,127 |
| S-2 * | Fellowship Hall, Chapel | 8,760 | 7:00 AM | 7:00 PM | 12 | 2,628 | 3 | 0.81 | 1.74 | 15,248 | 4,574 | 10,674 |
| S-3 * | Rec Room, Hobby Rooms | 8,760 | 7:00 AM | 7:00 PM | 12 | 3,504 | 3 | 0.81 | 1.74 | 15,248 | 6,099 | 9,149 |
| S-4 | Dining Room, Kitchen | 8,760 | 5:00 AM | 8:00 PM | 15 | 5,475 | 15 | 0.86 | 8.20 | 71,809 | 44,880 | 26,928 |
| S-6 * | Solarium | 8,760 | 7:00 AM | 7:00 PM | 12 | 2,628 | 3 | 0.81 | 1.74 | 15,248 | 4,574 | 10,674 |
| E-3 | 1st Floor, Lobby, Offices | 8,760 | 6:30 AM | 11:30 PM | 17 | 6,205 | 3 | 0.81 | 1.74 | 15,248 | 10,801 | 4,447 |
| E-4 * | Chapel | 8,760 | 7:00 AM | 7:00 PM | 12 | 2,628 | 1.5 | 0.80 | 0.88 | 7,719 | 2,316 | 5,404 |
| E-5 * | Hobby Rooms | 8,760 | 7:00 AM | 7:00 PM | 12 | 3,504 | 0.5 | 0.70 | 0.34 | 2,941 | 1,176 | 1,764 |
| E-7 | Kitchen | 8,761 | 5:00 AM | 8:00 PM | 15 | 5,475 | 3 | 0.81 | 1.74 | 15,250 | 9,530 | 5,720 |
| E-9 | Kitchen | 8,760 | 5:00 AM | 8:00 PM | 15 | 6,205 | 5 | 0.82 | 2.87 | 25,104 | 17,782 | 7,322 |
| E-12 | Kitchen | 8,760 | 5:00 AM | 8:00 PM | 15 | 5,475 | 5 | 0.82 | 2.87 | 25,104 | 15,690 | 9,414 |

* Occupancy Sensors Added to Reduce Post-Retrofit Operating Hours

| Heating and Cooling Savings | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Existing | | Proposed | | Savings | |
| Fan | cfm | Cooling kWh | Heating Therms | Cooling kWh | Heating Therms | Cooling kWh | Heating Therms |
| S-1 | 4,300 | 5,071 | 3,930 | 3,592 | 2,784 | 1,479 | 1,146 |
| S-2 | 1,340 | 1,580 | 1,225 | 474 | 367 | 1,106 | 857 |
| S-3 | 1,060 | 1,250 | 969 | 500 | 388 | 750 | 581 |
| S-4 | 18,960 | 22,361 | 17,329 | 13,975 | 10,831 | 8,385 | 6,498 |
| S-6 | 1,150 | 1,356 | 1,051 | 407 | 315 | 949 | 736 |

| Savings Summary | | |
|---|---|---|
| Fan | kWh | Therms |
| S1 and E3 | 20,054 | 1,146 |
| S2, S3, S6, E4, E5 | 40,470 | 2,174 |
| S4, E7, E12 | 50,447 | 6,498 |
| E-9 | 7,322 | N/A |
| Total | 118,304.67 | 9,819 |

Site 2488: Ex Post Impact Calculations

| Supply and Exhaust Fan Savings | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Post-Retrofit Conditions | | | | | | | | | |
| Fan | Serves | Pre-Retrofit Hours per Year | Start Time | Stop Time | Hours per Day | Hours per Year | Horsepower | Motor Full Load Efficiency | kW | Pre-Retrofit kWh | Post-Retrofit kWh | kWh Savings |
| S-1 | Lobby, Offices | 8,760 | 6:00 AM | 9:23 PM | 15 | 5,615 | 10 | 0.85 | 5.53 | 48,436 | 31,046 | 17,390 |
| S-2 * | Fellowship Hall, Chapel | 8,760 | 7:00 AM | 8:00 PM | 13 | 2,847 | 3 | 0.81 | 1.74 | 15,248 | 4,956 | 10,293 |
| S-3 * | Rec Room, Hobby Rooms | 8,760 | 6:00 AM | 8:00 PM | 14 | 4,088 | 3 | 0.81 | 1.74 | 15,248 | 7,116 | 8,132 |
| S-4 | Dining Room, Kitchen | 8,760 | 3:30 AM | 8:30 PM | 17 | 6,205 | 15 | 0.86 | 8.20 | 71,809 | 50,864 | 20,944 |
| S-6 * | Solarium | 8,760 | 7:00 AM | 7:00 PM | 12 | 2,628 | 3 | 0.81 | 1.74 | 15,248 | 4,574 | 10,674 |
| E-3 | 1st Floor, Lobby, Offices | 8,760 | 6:00 AM | 9:23 PM | 15 | 5,615 | 3 | 0.81 | 1.74 | 15,248 | 9,774 | 5,475 |
| E-4 * | Chapel | 8,760 | 7:00 AM | 8:00 PM | 13 | 2,847 | 1.5 | 0.80 | 0.88 | 7,719 | 2,509 | 5,211 |
| E-5 * | Hobby Rooms | 8,760 | 6:00 AM | 8:00 PM | 14 | 4,088 | 0.5 | 0.70 | 0.34 | 2,941 | 1,372 | 1,568 |
| E-7 | Kitchen | 8,760 | 3:30 AM | 8:30 PM | 17 | 6,205 | 3 | 0.81 | 1.74 | 15,248 | 10,801 | 4,447 |
| E-9 | Kitchen | 8,760 | 3:30 AM | 8:30 PM | 17 | 6,205 | 5 | 0.82 | 2.87 | 25,104 | 17,782 | 7,322 |
| E-12 | Kitchen | 8,760 | 3:30 AM | 8:30 PM | 17 | 6,205 | 5 | 0.82 | 2.87 | 25,104 | 17,782 | 7,322 |

* Occupancy Sensors Added to Reduce Post-Retrofit Operating Hours

| Heating and Cooling Savings | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Existing | | Proposed | | Savings | |
| Fan | cfm | Cooling kWh | Heating Therms | Cooling kWh | Heating Therms | Cooling kWh | Heating Therms |
| S-1 | 4,300 | 5,071 | 3,930 | 3,251 | 2,519 | 1,821 | 1,411 |
| S-2 | 1,340 | 1,580 | 1,225 | 514 | 398 | 1,067 | 827 |
| S-3 | 1,060 | 1,250 | 969 | 583 | 452 | 667 | 517 |
| S-4 | 18,960 | 22,361 | 17,329 | 15,839 | 12,275 | 6,522 | 5,054 |
| S-6 | 1,150 | 1,356 | 1,051 | 407 | 315 | 949 | 736 |

| Savings Summary | | |
|---|---|---|
| Fan | kWh | Therms |
| S1 and E3 | 24,685 | 1,411 |
| S2, S3, S6, E4, E5 | 38,561 | 2,079 |
| S4, E7, E12 | 39,235 | 5,054 |
| E-9 | 7,322 | N/A |
| Total | 109,803 | 8,545 |

**Other Customized Equipment (Site 2497)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | Other Customized Equipment |
| Site Description | Hotel |

**Measure Description**

The project consists of nine measures:
Measure 1: Install Variable Frequency Drives (VFD's) on two cooling tower fans, replacing spray nozzles, allow parallel fan operation, and lower the condenser water supply setpoint.
Measure 2: Correct reset controls to chiller 1 and 2.
Measure 3: Replace chilled water bypass valve with a motorized valve and trim impellers on the chilled water pumps to reduce flow.
Measure 4: Improve piping layout to eliminate pumping chilled water from the heat exchanger through the chiller.
Measure 5: Change air handler AC-1 from constant duct static pressure to reset based on most sensitive zone.
Measure 6: Adjust fan staging to allow more frequent parallel operation of three fans in AC-1.
Measure 7: Install an outside air economizer for AC-1.
Measure 8: Modify existing VAV boxes from 50% open to 20% open to decrease cooling during unoccupied times.
Measure 9: Remove obsolete inlet guide vanes from the existing fans in AC-1.

**Summary of Ex-Ante Impact Calculations**

A Spreadsheet model was developed which calculates the pre- and post-retrofit energy usage of the HVAC system.

**Comments on PG&E Calculations**

The baseline for this project is the pre-retrofit HVAC system. The original ex-ante calculations were modified to reflect more accurate cooling tower fan motor efficiencies for measure 1, but the final ex-ante impacts do not reflect this modification.

**Evaluation Process**

The evaluation process consisted of reviewing the application form and supporting documentation, and obtaining the electronic spreadsheet used for the ex-ante calculations.

The original and revised ex-ante impact calculations were examined in detail. The revised ex-ante impact calculations represent a more accurate estimate of the impact for this retrofit, and are accepted as the ex-post impact estimate. The ex-post impact estimate is higher than the ex-ante estimate for both energy and demand.

**Additional Notes**

The site also installed an EMS at the time of the retrofit, thereby saving more energy.

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 75.3 | 1,025,633.9 | 0 |
| **Adjusted Engineering** | 83.17 | 1,076,033.55 | 0 |
| **Engineering Realization Rate** | 1.10 | 1.05 | N/A |

Site 2497: Results

| | Demand | Energy | Therms |
|---|---|---|---|
| MDSS | 75.30 | 1025633.90 | 0.00 |
| QC | 83.17 | 1076033.55 | 0.00 |
| Realization Rate | 1.10 | 1.05 | N/A |

## Order of Application and Summary of the Measure Savings

| Order | End Use | Measure | Existing kWh | Proposed kWh | Energy Savings | Existing Peak kW | Proposed Peak kW | Demand Reduction |
|---|---|---|---|---|---|---|---|---|
| 1 | Cooling Tower Fans | 1 | **140,121** | **47,486** | 92,634 | **33.2** | **14.0** | 19.2 |
| 2 | Chillers | 7 | **773,921** | 576,779 | 197,142 | **279.0** | 279.0 | 0.0 |
| 3 | Chillers | 1 | 576,779 | 426,551 | 150,228 | 279.0 | 249.3 | 29.7 |
| 4 | Chillers | 2 | 426,551 | 413,225 | 13,326 | 249.3 | 249.3 | 0.0 |
| 5 | Chillers | 8 | 413,225 | 271,581 | 141,644 | 249.3 | 249.3 | 0.0 |
| 6 | Chillers | 9 | 271,581 | 270,241 | 1,340 | 249.3 | 236.9 | 12.5 |
| 7 | Chillers | 6 | 270,241 | 268,028 | 2,213 | 236.9 | 236.9 | 0.0 |
| 8 | Chillers | 5 | 268,028 | **263,060** | 4,968 | 236.9 | **236.9** | 0.0 |
| 9 | Chilled Water Pumps | 3 | **416,498** | 321,520 | 94,978 | **48.1** | 34.6 | 13.5 |
| 10 | Chilled Water Pumps | 4 | 321,520 | **299,492** | 22,028 | 34.6 | **34.6** | 0.0 |
| 11 | Air Handler AC-1 | 8 | **604,440** | 349,341 | 255,099 | **167.9** | 167.9 | 0.0 |
| 12 | Air Handler AC-2 | 9 | 349,341 | 331,874 | 17,467 | 167.9 | 159.5 | 8.4 |
| 13 | Air Handler AC-3 | 6 | 331,874 | 313,659 | 18,215 | 159.5 | 159.5 | 0.0 |
| 14 | Air Handler AC-4 | 5 | 313,659 | **248,907** | 64,752 | 159.5 | **159.5** | 0.0 |
| | | | | **Total:** | **1,076,034** | | **Total:** | **83.2** |

## Cross Reference of Measures (Attachment 7 vs Site Survey)

| Att. 7 | Site Survey | Existing kWh | Proposed kWh | Energy Savings | Existing Peak kW | Proposed Peak kW | Demand Reduction |
|---|---|---|---|---|---|---|---|
| Measure 1 | Equipment Measure 2 | 716,900 | 474,037 | 242,863 | 312.2 | 263.3 | 48.9 |
| Measure 2 | Control System Measure 4 | 426,551 | 413,225 | 13,326 | 249.3 | 249.3 | 0.0 |
| Measure 3 | Equipment Measures 3 & 6 | 416,498 | 321,520 | 94,978 | 48.1 | 34.6 | 13.5 |
| Measure 4 | Equipment Measure 5 | 321,520 | 299,492 | 22,028 | 34.6 | 34.6 | 0.0 |
| Measure 5 | Control System Measure 3 | 581,687 | 511,967 | 69,719 | 396.3 | 396.3 | 0.0 |
| Measure 6 | Control System Measure 2 | 602,115 | 581,687 | 20,428 | 396.3 | 396.3 | 0.0 |
| Measure 7 | Equipment Measure 1 | 773,921 | 576,779 | 197,142 | 279.0 | 279.0 | 0.0 |
| Measure 8 | Control System Measure 1 | 1,017,665 | 620,922 | 396,742 | 417.2 | 417.2 | 0.0 |
| Measure 9 | Equipment Measure 4 | 620,922 | 602,115 | 18,807 | 417.2 | 396.3 | 20.9 |
| | | | **Total:** | **1,076,034** | | **Total:** | **83.2** |

*Notes:*

Some measures achieve savings in more than one end use. These measures are listed twice in the upper table to reflect the impact on both end-uses. For example, measure 8 results in both AC-1 fan motor savings and chiller savings.

The order of application measures table is intended insure that energy savings in a specific end use are not double counted.

The attached nine measure analysis summaries relate to the nine measures listed in the cross reference table. The measure data reflected in Attachment 7 are found in these analyses.

# Existing Tower Operation Analysis

**(Single 2-Speed Tower and 15 Degree F Approach)**

| OA Temp | Average Wet Bulb Temperature (binned average TMY data) | Hours | Average Building Cooling Load (assumed to never drop below 40 tons) | Chiller Efficiency (kW/ton) | Heat Rejected to Tower (Mbtu/hr) | Percent Fan Power Required | Motor Efficiency | Tower Fan Demand (kW) | Total Fan Energy (kWh) |
|---|---|---|---|---|---|---|---|---|---|
| 31 | 28.0 | 1 | 40 | - | 544.90 | 0% | - | - | - |
| 32 | 29.5 | 4 | 40 | - | 544.90 | 0% | - | - | - |
| 33 | 30.4 | 7 | 40 | - | 544.90 | 0% | - | - | - |
| 34 | 31.3 | 8 | 40 | - | 544.90 | 0% | - | - | - |
| 35 | 32.6 | 7 | 40 | - | 544.90 | 0% | - | - | - |
| 36 | 32.8 | 16 | 40 | - | 544.90 | 0% | - | - | - |
| 37 | 32.8 | 13 | 40 | - | 544.90 | 0% | - | - | - |
| 38 | 34.9 | 18 | 40 | - | 544.90 | 0% | - | - | - |
| 39 | 36.0 | 27 | 40 | - | 544.90 | 0% | - | - | - |
| 40 | 37.5 | 52 | 40 | - | 544.90 | 25% | 0.86 | 8.7 | 454 |
| 41 | 38.3 | 46 | 40 | - | 544.90 | 25% | 0.86 | 8.7 | 401 |
| 42 | 39.3 | 66 | 40 | - | 544.90 | 25% | 0.86 | 8.7 | 576 |
| 43 | 40.4 | 82 | 40 | - | 544.90 | 25% | 0.86 | 8.7 | 715 |
| 44 | 40.9 | 120 | 40 | - | 544.90 | 25% | 0.86 | 8.7 | 1,047 |
| 45 | 42.2 | 121 | 40 | - | 544.90 | 25% | 0.86 | 8.7 | 1,056 |
| 46 | 42.9 | 147 | 40 | - | 544.90 | 25% | 0.86 | 8.7 | 1,283 |
| 47 | 44.0 | 190 | 40 | - | 544.90 | 25% | 0.86 | 8.7 | 1,658 |
| 48 | 45.1 | 191 | 40 | - | 544.90 | 25% | 0.86 | 8.7 | 1,667 |
| 49 | 45.8 | 265 | 40 | - | 544.90 | 25% | 0.86 | 8.7 | 2,312 |
| 50 | 46.6 | 267 | 40 | 1.12 | 697.80 | 25% | 0.86 | 8.7 | 2,330 |
| 51 | 47.7 | 363 | 40 | 1.12 | 697.80 | 25% | 0.86 | 8.7 | 3,167 |
| 52 | 48.3 | 384 | 40 | 1.12 | 697.80 | 25% | 0.86 | 8.7 | 3,350 |
| 53 | 49.4 | 435 | 40 | 1.12 | 697.80 | 25% | 0.86 | 8.7 | 3,795 |
| 54 | 50.4 | 427 | 53.75 | 1.01 | 895.18 | 25% | 0.86 | 8.7 | 3,726 |
| 55 | 51.2 | 455 | 78.125 | 0.84 | 1,226.38 | 25% | 0.86 | 8.7 | 3,970 |
| 56 | 52.2 | 504 | 102.5 | 0.73 | 1,550.28 | 25% | 0.86 | 8.7 | 4,397 |
| 57 | 53.2 | 475 | 126.875 | 0.62 | 1,855.87 | 25% | 0.86 | 8.7 | 4,144 |
| 58 | 53.7 | 539 | 151.25 | 0.56 | 2,168.98 | 25% | 0.86 | 8.7 | 4,703 |
| 59 | 54.3 | 455 | 175.625 | 0.53 | 2,490.08 | 25% | 0.86 | 8.7 | 3,970 |
| 60 | 55.2 | 432 | 200 | 0.51 | 2,813.02 | 25% | 0.86 | 8.7 | 3,769 |
| 61 | 55.6 | 343 | 224.375 | 0.51 | 3,147.95 | 100% | 0.90 | 33.2 | 11,372 |
| 62 | 56.4 | 309 | 248.75 | 0.53 | 3,499.86 | 100% | 0.90 | 33.2 | 10,245 |
| 63 | 56.8 | 210 | 273.125 | 0.54 | 3,845.77 | 100% | 0.90 | 33.2 | 6,963 |
| 64 | 57.5 | 234 | 297.5 | 0.57 | 4,213.66 | 100% | 0.90 | 33.2 | 7,758 |
| 65 | 57.9 | 230 | 321.875 | 0.59 | 4,575.55 | 100% | 0.90 | 33.2 | 7,626 |
| 66 | 58.8 | 159 | 346.25 | 0.61 | 4,940.77 | 100% | 0.90 | 33.2 | 5,272 |
| 67 | 59.1 | 174 | 370.625 | 0.62 | 5,296.66 | 100% | 0.90 | 33.2 | 5,769 |
| 68 | 59.8 | 133 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 4,410 |
| 69 | 60.2 | 146 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 4,841 |
| 70 | 60.8 | 110 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 3,647 |
| 71 | 61.4 | 132 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 4,377 |
| 72 | 62.1 | 92 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 3,050 |
| 73 | 61.9 | 60 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 1,989 |
| 74 | 62.4 | 79 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 2,619 |
| 75 | 61.9 | 38 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 1,260 |
| 76 | 61.8 | 33 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 1,094 |
| 77 | 61.5 | 23 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 763 |
| 78 | 61.6 | 26 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 862 |
| 79 | 62.8 | 12 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 398 |
| 80 | 62.5 | 18 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 597 |
| 81 | 62.8 | 11 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 365 |
| 82 | 63.5 | 16 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 530 |
| 83 | 63.4 | 11 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 365 |
| 84 | 63.6 | 11 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 365 |
| 85 | 63.6 | 5 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 166 |
| 86 | 63.4 | 5 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 166 |
| 87 | 64.3 | 8 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 265 |
| 88 | 65.7 | 7 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 232 |
| 89 | 64.7 | 6 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 199 |
| 90 | 65.5 | 2 | 390 | 0.63 | 5,583.47 | 100% | 0.90 | 33.2 | 66 |
| **Totals:** | | **8760** | | | | | | **33.2** | **140,121** |

## Proposed Tower Operation Analysis

**(Two Towers with Parallel Fans and 5 Degree F Approach)**

| OA Temp | Average Wet Bulb Temperature (binned average TMY data) | Hours | Average Building Cooling Load (assumed to never drop below 40 tons) | Chiller Efficiency (kW/ton) | Heat Rejected to Tower (Mbtu/hr) | CHWS Reset Temperature | Proposed CWST (Based on 5 F Approach with a 15 Delta from CHWST) | Percent CFM From One Fan Required | Total Fan Brake Horsepower Required (both towers)* | 40 HP Motor Efficiency | Tower Fan Demand (kW) | VFD Efficiency (from Asea Brown Boveri - "ABB") | Total Fan Energy (kWh) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | 28.0 | 1 | 40 | - | 544.90 | 0.0 | N/A | 0% | 0.0 | - | - | - | - |
| 32 | 29.5 | 4 | 40 | - - | 544.90 | 0.0 | N/A | 0% | 0.0 | - | - | - | - |
| 33 | 30.4 | 7 | 40 | - | 544.90 | 0.0 | N/A | 0% | 0.0 | - | - | - | - |
| 34 | 31.3 | 8 | 40 | - | 544.90 | 0.0 | N/A | 0% | 0.0 | - | - | - | - |
| 35 | 32.6 | 7 | 40 | - | 544.90 | 0.0 | N/A | 0% | 0.0 | - | - | - | - |
| 36 | 32.8 | 16 | 40 | - | 544.90 | 0.0 | N/A | 0% | 0.0 | - | - | - | - |
| 37 | 32.8 | 13 | 40 | - | 544.90 | 0.0 | N/A | 0% | 0.0 | - | - | - | - |
| 38 | 34.9 | 18 | 40 | - | 544.90 | 0.0 | N/A | 0% | 0.0 | - | - | - | - |
| 39 | 36.0 | 27 | 40 | - | 544.90 | 0.0 | N/A | 0% | 0.0 | - | - | - | - |
| 40 | 37.5 | 52 | 40 | - | 544.90 | 50.4 | 53.40 | 12% | 1.2 | 0.935 | 1.0 | 0.94 | 53 |
| 41 | 38.3 | 46 | 40 | - | 544.90 | 50.4 | 53.40 | 12% | 1.2 | 0.935 | 1.0 | 0.94 | 48 |
| 42 | 39.3 | 66 | 40 | - | 544.90 | 50.4 | 53.40 | 13% | 1.3 | 0.935 | 1.0 | 0.94 | 71 |
| 43 | 40.4 | 82 | 40 | - | 544.90 | 50.4 | 53.40 | 13% | 1.3 | 0.935 | 1.0 | 0.94 | 90 |
| 44 | 40.9 | 120 | 40 | - | 544.90 | 50.4 | 53.40 | 13% | 1.3 | 0.935 | 1.0 | 0.94 | 133 |
| 45 | 42.2 | 121 | 40 | - | 544.90 | 50.4 | 53.40 | 14% | 1.4 | 0.935 | 1.1 | 0.94 | 139 |
| 46 | 42.9 | 147 | 40 | - | 544.90 | 50.4 | 53.40 | 14% | 1.4 | 0.935 | 1.1 | 0.94 | 172 |
| 47 | 44.0 | 190 | 40 | - | 544.90 | 50.4 | 53.40 | 14% | 1.4 | 0.935 | 1.1 | 0.94 | 227 |
| 48 | 45.1 | 191 | 40 | - | 544.90 | 50.4 | 53.40 | 14% | 1.4 | 0.935 | 1.2 | 0.94 | 234 |
| 49 | 45.8 | 265 | 40 | - | 544.90 | 50.4 | 53.40 | 15% | 1.5 | 0.935 | 1.2 | 0.94 | 330 |
| 50 | 46.6 | 267 | 40 | - | 544.90 | 50.4 | 53.40 | 15% | 1.5 | 0.935 | 1.2 | 0.94 | 338 |
| 51 | 47.7 | 363 | 40 | - | 544.90 | 50.4 | 53.40 | 15% | 1.5 | 0.935 | 1.2 | 0.94 | 470 |
| 52 | 48.3 | 384 | 40 | - | 544.90 | 50.4 | 53.40 | 15% | 1.5 | 0.935 | 1.2 | 0.94 | 504 |
| 53 | 49.4 | 435 | 40 | - | 544.90 | 50.4 | 54.38 | 16% | 1.6 | 0.935 | 1.3 | 0.94 | 584 |
| 54 | 50.4 | 427 | 53.75 | - | 709.90 | 50.4 | 55.40 | 21% | 2.1 | 0.935 | 1.6 | 0.94 | 746 |
| 55 | 51.2 | 455 | 78.125 | - | 1,002.40 | 50.4 | 56.15 | 29% | 2.9 | 0.935 | 2.3 | 0.94 | 1,123 |
| 56 | 52.2 | 504 | 102.5 | - | 1,294.90 | 50.4 | 57.16 | 38% | 3.8 | 0.935 | 3.0 | 0.94 | 1,607 |
| 57 | 53.2 | 475 | 126.875 | 0.55 | 1,826.34 | 52.0 | 67.00 | 53% | 5.3 | 0.935 | 4.2 | 0.94 | 2,136 |
| 58 | 53.7 | 539 | 151.25 | 0.50 | 2,137.18 | 52.0 | 67.00 | 62% | 6.2 | 0.935 | 4.9 | 0.94 | 2,836 |
| 59 | 54.3 | 455 | 175.625 | 0.47 | 2,455.14 | 52.0 | 67.00 | 71% | 7.1 | 0.935 | 5.7 | 0.94 | 2,751 |
| 60 | 55.2 | 432 | 200 | 0.45 | 2,774.73 | 52.0 | 67.00 | 80% | 8.0 | 0.935 | 6.4 | 0.94 | 2,952 |
| 61 | 55.6 | 343 | 224.375 | 0.45 | 3,104.99 | 52.0 | 67.00 | 90% | 9.0 | 0.935 | 7.2 | 0.94 | 2,622 |
| 62 | 56.4 | 309 | 248.75 | 0.47 | 3,450.36 | 52.0 | 67.00 | 100% | 10.0 | 0.935 | 8.0 | 0.94 | 2,625 |
| 63 | 56.8 | 210 | 273.125 | 0.48 | 3,790.40 | 51.0 | 66.00 | 110% | 11.0 | 0.935 | 8.8 | 0.94 | 1,960 |
| 64 | 57.5 | 234 | 297.5 | 0.51 | 4,149.99 | 50.0 | 65.00 | 120% | 12.0 | 0.935 | 9.6 | 0.94 | 2,391 |
| 65 | 57.9 | 230 | 321.875 | 0.53 | 4,504.25 | 49.0 | 64.00 | 131% | 13.1 | 0.935 | 10.4 | 0.94 | 2,551 |
| 66 | 58.8 | 159 | 346.25 | 0.54 | 4,861.47 | 48.0 | 63.82 | 141% | 14.1 | 0.935 | 11.3 | 0.94 | 1,903 |
| 67 | 59.1 | 174 | 370.625 | 0.55 | 5,210.39 | 47.0 | 64.11 | 151% | 15.1 | 0.935 | 12.1 | 0.94 | 2,232 |
| 68 | 59.8 | 133 | 390 | 0.56 | 5,491.23 | 46.0 | 64.82 | 159% | 15.9 | 0.935 | 12.7 | 0.94 | 1,798 |
| 69 | 60.2 | 146 | 390 | 0.56 | 5,491.23 | 45.0 | 65.25 | 160% | 16.0 | 0.935 | 12.8 | 0.94 | 1,988 |
| 70 | 60.8 | 110 | 390 | 0.56 | 5,491.23 | 44.0 | 65.84 | 162% | 16.2 | 0.935 | 12.9 | 0.94 | 1,513 |
| 71 | 61.4 | 132 | 390 | 0.56 | 5,491.23 | 43.0 | 66.43 | 164% | 16.4 | 0.935 | 13.1 | 0.94 | 1,833 |
| 72 | 62.1 | 92 | 390 | 0.56 | 5,491.23 | 42.0 | 67.05 | 165% | 16.5 | 0.935 | 13.2 | 0.94 | 1,290 |
| 73 | 61.9 | 60 | 390 | 0.56 | 5,491.23 | 42.0 | 66.93 | 165% | 16.5 | 0.935 | 13.2 | 0.94 | 840 |
| 74 | 62.4 | 79 | 390 | 0.56 | 5,491.23 | 42.0 | 67.35 | 166% | 16.6 | 0.935 | 13.2 | 0.94 | 1,113 |
| 75 | 61.9 | 38 | 390 | 0.56 | 5,491.23 | 42.0 | 66.92 | 165% | 16.5 | 0.935 | 13.2 | 0.94 | 532 |
| 76 | 61.8 | 33 | 390 | 0.56 | 5,491.23 | 42.0 | 66.79 | 165% | 16.5 | 0.935 | 13.1 | 0.94 | 461 |
| 77 | 61.5 | 23 | 390 | 0.56 | 5,491.23 | 42.0 | 66.48 | 164% | 16.4 | 0.935 | 13.1 | 0.94 | 320 |
| 78 | 61.6 | 26 | 390 | 0.56 | 5,491.23 | 42.0 | 66.58 | 164% | 16.4 | 0.935 | 13.1 | 0.94 | 362 |
| 79 | 62.8 | 12 | 390 | 0.56 | 5,491.23 | 42.0 | 67.83 | 167% | 16.7 | 0.935 | 13.4 | 0.94 | 170 |
| 80 | 62.5 | 18 | 390 | 0.56 | 5,491.23 | 42.0 | 67.50 | 166% | 16.6 | 0.935 | 13.3 | 0.94 | 254 |
| 81 | 62.8 | 11 | 390 | 0.56 | 5,491.23 | 42.0 | 67.82 | 167% | 16.7 | 0.935 | 13.3 | 0.94 | 156 |
| 82 | 63.5 | 16 | 390 | 0.56 | 5,491.23 | 42.0 | 68.50 | 169% | 16.9 | 0.935 | 13.5 | 0.94 | 230 |
| 83 | 63.4 | 11 | 390 | 0.56 | 5,491.23 | 42.0 | 68.36 | 169% | 16.9 | 0.935 | 13.5 | 0.94 | 158 |
| 84 | 63.6 | 11 | 390 | 0.56 | 5,491.23 | 42.0 | 68.64 | 169% | 16.9 | 0.935 | 13.5 | 0.94 | 158 |
| 85 | 63.6 | 5 | 390 | 0.56 | 5,491.23 | 42.0 | 68.60 | 169% | 16.9 | 0.935 | 13.5 | 0.94 | 72 |
| 86 | 63.4 | 5 | 390 | 0.56 | 5,491.23 | 42.0 | 68.40 | 169% | 16.9 | 0.935 | 13.5 | 0.94 | 72 |
| 87 | 64.3 | 8 | 390 | 0.56 | 5,491.23 | 42.0 | 69.25 | 171% | 17.1 | 0.935 | 13.7 | 0.94 | 116 |
| 88 | 65.7 | 7 | 390 | 0.56 | 5,491.23 | 42.0 | 70.71 | 175% | 17.5 | 0.935 | 14.0 | 0.94 | 104 |
| 89 | 64.7 | 6 | 390 | 0.56 | 5,491.23 | 42.0 | 69.67 | 172% | 17.2 | 0.935 | 13.7 | 0.94 | 88 |
| 90 | 65.5 | 2 | 390 | 0.56 | 5,491.23 | 42.0 | 70.50 | 174% | 17.4 | 0.935 | 13.9 | 0.94 | 30 |
| **Totals:** | | **8760** | | | | | | | | | **14.0** | | **47,486** |

* The 40 HP motors should not be operated below about 33% of rated output (or about 27 HP) and the values inculded here are average powers at each bin since the fans will cycle off and on to maintain the 5 degree approach. Motor and VFD efficencies below the 33% condition are for the respective systems are for actual minimum speed (33%). This is a conservative assumption since this is the lowest efficiency in both cases.

# Chiller Load Regression and Binned Weather Analysis

| OA Temp | Hours | Percent | Chiller 1 Tons (based on measured data and regression) | Chiller 2 Tons (based on measured data and regression) | Average Building Cooling Load (assumed to never drop below 40 tons) | Total Building Ton-hour Requirement |
|---|---|---|---|---|---|---|
| 31 | 1 | 0.01% | -380 | -634 | 40 | 40 |
| 32 | 4 | 0.05% | -360 | -605 | 40 | 160 |
| 33 | 7 | 0.08% | -340 | -576 | 40 | 280 |
| 34 | 8 | 0.09% | -320 | -548 | 40 | 320 |
| 35 | 7 | 0.08% | -300 | -519 | 40 | 280 |
| 36 | 16 | 0.18% | -280 | -490 | 40 | 640 |
| 37 | 13 | 0.15% | -260 | -461 | 40 | 520 |
| 38 | 18 | 0.21% | -240 | -433 | 40 | 720 |
| 39 | 27 | 0.31% | -220 | -404 | 40 | 1,080 |
| 40 | 52 | 0.59% | -200 | -375 | 40 | 2,080 |
| 41 | 46 | 0.53% | -180 | -346 | 40 | 1,840 |
| 42 | 66 | 0.75% | -160 | -318 | 40 | 2,640 |
| 43 | 82 | 0.94% | -140 | -289 | 40 | 3,280 |
| 44 | 120 | 1.37% | -120 | -260 | 40 | 4,800 |
| 45 | 121 | 1.38% | -100 | -231 | 40 | 4,840 |
| 46 | 147 | 1.68% | -80 | -203 | 40 | 5,880 |
| 47 | 190 | 2.17% | -60 | -174 | 40 | 7,600 |
| 48 | 191 | 2.18% | -40 | -145 | 40 | 7,640 |
| 49 | 265 | 3.03% | -20 | -116 | 40 | 10,600 |
| 50 | 267 | 3.05% | 0 | -88 | 40 | 10,680 |
| 51 | 363 | 4.14% | 20 | -59 | 40 | 14,520 |
| 52 | 384 | 4.38% | 40 | -30 | 40 | 15,360 |
| 53 | 435 | 4.97% | 60 | -1 | 40 | 17,400 |
| 54 | 427 | 4.87% | 80 | 28 | 54 | 22,951 |
| 55 | 455 | 5.19% | 100 | 56 | 78 | 35,547 |
| 56 | 504 | 5.75% | 120 | 85 | 103 | 51,660 |
| 57 | 475 | 5.42% | 140 | 114 | 127 | 60,266 |
| 58 | 539 | 6.15% | 160 | 143 | 151 | 81,524 |
| 59 | 455 | 5.19% | 180 | 171 | 176 | 79,909 |
| 60 | 432 | 4.93% | 200 | 200 | 200 | 86,400 |
| 61 | 343 | 3.92% | 220 | 229 | 224 | 76,961 |
| 62 | 309 | 3.53% | 240 | 258 | 249 | 76,864 |
| 63 | 210 | 2.40% | 260 | 286 | 273 | 57,356 |
| 64 | 234 | 2.67% | 280 | 315 | 298 | 69,615 |
| 65 | 230 | 2.63% | 300 | 344 | 322 | 74,031 |
| 66 | 159 | 1.82% | 320 | 373 | 346 | 55,054 |
| 67 | 174 | 1.99% | 340 | 401 | 371 | 64,489 |
| 68 | 133 | 1.52% | 360 | 420 | 390 | 51,870 |
| 69 | 146 | 1.67% | 360 | 420 | 390 | 56,940 |
| 70 | 110 | 1.26% | 360 | 420 | 390 | 42,900 |
| 71 | 132 | 1.51% | 360 | 420 | 390 | 51,480 |
| 72 | 92 | 1.05% | 360 | 420 | 390 | 35,880 |
| 73 | 60 | 0.68% | 360 | 420 | 390 | 23,400 |
| 74 | 79 | 0.90% | 360 | 420 | 390 | 30,810 |
| 75 | 38 | 0.43% | 360 | 420 | 390 | 14,820 |
| 76 | 33 | 0.38% | 360 | 420 | 390 | 12,870 |
| 77 | 23 | 0.26% | 360 | 420 | 390 | 8,970 |
| 78 | 26 | 0.30% | 360 | 420 | 390 | 10,140 |
| 79 | 12 | 0.14% | 360 | 420 | 390 | 4,680 |
| 80 | 18 | 0.21% | 360 | 420 | 390 | 7,020 |
| 81 | 11 | 0.13% | 360 | 420 | 390 | 4,290 |
| 82 | 16 | 0.18% | 360 | 420 | 390 | 6,240 |
| 83 | 11 | 0.13% | 360 | 420 | 390 | 4,290 |
| 84 | 11 | 0.13% | 360 | 420 | 390 | 4,290 |
| 85 | 5 | 0.06% | 360 | 420 | 390 | 1,950 |
| 86 | 5 | 0.06% | 360 | 420 | 390 | 1,950 |
| 87 | 8 | 0.09% | 360 | 420 | 390 | 3,120 |
| 88 | 7 | 0.08% | 360 | 420 | 390 | 2,730 |
| 89 | 6 | 0.07% | 360 | 420 | 390 | 2,340 |
| 90 | 2 | 0.02% | 360 | 420 | 390 | 780 |
| Totals: | 8760 | | | | | 1,389,586 |

Note: chiller tonnage for each chiller peaks at the measured maximum for that chiller

## Chiller Energy Consumption with existing free cooling

| | |
|---|---|
| 49 | Free cooling activation temperature |
| 1,334,346 | Average ton-hours when outside air temp is between 50 and 90 degrees F |
| 0.58 | Average chiller efficiency (kw/ton) |
| 773,921 | Annual kWh |
| $61,914 | Annual chiller electricity cost |

## Building Load Regression*

| Coefficients for Chillers vs OAT | | |
|---|---|---|
| | Slope | Y-intercept |
| Chiller 2 | 28.75 | -1525 |
| Chiller 1 | 20 | -1000 |

* Regression is based on measured chiller data and was used to determine slope of a best fit straight line for chiller load (see the chiller load data/graph in site survey report)

# Hyatt Regency Energy Saving Measures

### *Measure 1: Retrofit Cooling Towers and Condenser Water System*

***End Use: Cooling Tower Fans***

| | | |
|---|---|---|
| Total Tower Fan Motor Capacity (2 x 40) | 80 *hp* | |
| Number of Cells Normally Operating Simultaneously | 1 | Hyatt engineering staff |
| Proposed Number of Cells Operating Simultaneously | 2 | |
| Average Fan Motor Power | 12.8 *kW* | Measured |
| Percent Savings | 37.5% | Half of cube law savings due to increased energy for low CWST |
| Existing Peak Fan Power | 33.2 *kW* | Single tower at full speed |
| Peak Fan Demand Reduction | 19.2 *kW* | Single cell to two cells |
| Proposed Peak Fan Power | 14.0 *kW* | |
| Existing Annual Hours of Tower Operation | 8,760 *hrs/yr* | Building operates in either free cooling or chiller cooling for the entire year |
| Existing Average Tower Fan Energy Use | 140,121 *kWh/yr* | |
| Proposed Average Tower Fan Energy Use | 47,486 *kWh/yr* | |
| Tower Fan Energy Savings | 92,634 *kWh/yr* | |

***End Use: Chillers***

| | | |
|---|---|---|
| Total Ton-hours of Chiller Cooling with Economizer and Existing Free Cooling Operation | 994,447 *Ton-hours/yr* | Attached binned weather and economizer analyses |
| Total Ton-hours of Chiller Cooling with Economizer and New Free Cooling Operation | 826,329 *Ton-hours/yr* | Attached binned weather analysis |
| Chiller 2 Efficiency at Existing CWST of 78 F | 0.58 *kW/ton* | Measured (conservative assumption - chiller 2 is the most efficient of the chillers) |
| Chiller 2 Efficiency at New CWST of 67 F | 0.52 *kW/ton* | Using manufacturer's data for CWST vs efficiency |
| Existing Peak Chiller Power | 279 *kW* | One chiller at max. tons (465) - unchanged by measure 7 |
| Chiller Peak Demand Reduction | 29.7 *kW* | |
| Proposed Peak Chiller Demand | 249 *kW* | |
| Existing Average Chiller Energy Use | 576,779 *kWh/yr* | |
| Average Chiller Energy Use after Free Cooling is Improved | 479,271 *kWh/yr* | Based upon proposed use after economizer and free cooling changes are complete |
| Proposed Average Chiller Energy Use | 426,551 *kWh/yr* | Including improved chiller efficiency |
| Total Chiller Energy Savings | 150,228 *kWh/yr* | |

| | | |
|---|---|---|
| Total Measure Savings | 242,863 *kWh/yr* | |
| Average Cost of Electricity | $0.08 *per kWh* | |
| Annual Cost Savings | $19,429 *per year* | Not including peak demand savings |
| Cost to Supply and Install VFD, Modify Control Logic, and to Retrofit Piping System | $54,000 | |

***Measure Description***

Add one variable speed drive to drive both cooling tower fans synchronously. Change the control algorithm to modulate the fans' speed to a specified approach temperature. The condenser water supply temperature will likely reach 67 F. The condenser water supply temperature setpoint shall be controlled to 5 F above the measured wet-bulb temperature. Tower fan energy savings are smaller due to the increase in CFM in order to further lower the CWST. Chiller 2 is modelled due to its better measured efficiency, rather than the average measured efficiency for both chillers, resulting in smaller predicted savings.

Proper piping design for this application would suggest a total 60' of head across the pump resulting from about 30' of pipe-loss, 15' across the condenser barrel, and a 15' rise in elevation at the cooling tower. The reduced head can be achieved with improved piping design including the use of long-radius elbows, 45 degree take-offs, removal of redundant valves and pipes, etc. Pricing includes new nozzles for the tower to improve efficiency at the new flow. See the enclosed drawings. In order to maintain design flow at the lower head, the pump impellers must also be trimmed.

# Free Cooling Operation Binned Weather Analysis

| OA Temp | Hours | Percent | Chiller 1 Tons (based on measured data and regression) | Chiller 2 Tons (based on measured data and regression) | Average Building Cooling Load (assumed to never drop below 40 tons) | Total Building Ton-hour Requirement | Average Wet Bulb Temperature (binned average TMY data) | Existing Condenser Water Temperature (Measured Average Approach = 15 Deg F) | Base Case Ton-hours of Free Cooling with Existing Free Cooling Operation | Base Case Chiller Energy Use (no economizer and existing free cooling operation) | Reduced Tons Adjusting for Economizer (from economizer bin analysis) | Chiller Ton-hours (after economizer has been activated with existing free cooling operation) | Proposed Condenser Water Temperature (Approach = 5 Deg F) | Proposed Ton-hours of Free Cooling with Cooling Tower Improvements | Proposed Chiller Ton-hours (after economizer and new free cooling operation have been implemented) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | 1 | 0.01% | -380 | -634 | 40 | 40 | 28.0 | 43.0 | 0 | 0 | 0 | 0 | 33.0 | 0 | 0 |
| 32 | 4 | 0.05% | -360 | -605 | 40 | 160 | 29.5 | 44.5 | 0 | 0 | 0 | 0 | 34.5 | 0 | 0 |
| 33 | 7 | 0.08% | -340 | -576 | 40 | 280 | 30.4 | 45.4 | 0 | 0 | 0 | 0 | 35.4 | 0 | 0 |
| 34 | 8 | 0.09% | -320 | -548 | 40 | 320 | 31.3 | 46.3 | 0 | 0 | 0 | 0 | 36.3 | 0 | 0 |
| 35 | 7 | 0.08% | -300 | -519 | 40 | 280 | 32.6 | 47.6 | 0 | 0 | 0 | 0 | 37.6 | 0 | 0 |
| 36 | 16 | 0.18% | -280 | -490 | 40 | 640 | 32.8 | 47.8 | 0 | 0 | 0 | 0 | 37.8 | 0 | 0 |
| 37 | 13 | 0.15% | -260 | -461 | 40 | 520 | 32.8 | 47.8 | 0 | 0 | 0 | 0 | 37.8 | 0 | 0 |
| 38 | 18 | 0.21% | -240 | -433 | 40 | 720 | 34.9 | 49.9 | 0 | 0 | 0 | 0 | 39.9 | 0 | 0 |
| 39 | 27 | 0.31% | -220 | -404 | 40 | 1,080 | 36.0 | 51.0 | 0 | 0 | 0 | 0 | 41.0 | 0 | 0 |
| 40 | 52 | 0.59% | -200 | -375 | 40 | 2,080 | 37.5 | **52.5** | 2,080 | 0 | 0 | 0 | **42.5** | 2,080 | 0 |
| 41 | 46 | 0.53% | -180 | -346 | 40 | 1,840 | 38.3 | **53.3** | 1,840 | 0 | 0 | 0 | **43.3** | 1,840 | 0 |
| 42 | 66 | 0.75% | -160 | -318 | 40 | 2,640 | 39.3 | **54.3** | 2,640 | 0 | 0 | 0 | **44.3** | 2,640 | 0 |
| 43 | 82 | 0.94% | -140 | -289 | 40 | 3,280 | 40.4 | **55.4** | 3,280 | 0 | 0 | 0 | **45.4** | 3,280 | 0 |
| 44 | 120 | 1.37% | -120 | -260 | 40 | 4,800 | 40.9 | **55.9** | 4,800 | 0 | 0 | 0 | **45.9** | 4,800 | 0 |
| 45 | 121 | 1.38% | -100 | -231 | 40 | 4,840 | 42.2 | **57.2** | 4,840 | 0 | 0 | 0 | **47.2** | 4,840 | 0 |
| 46 | 147 | 1.68% | -80 | -203 | 40 | 5,880 | 42.9 | **57.9** | 5,880 | 0 | 0 | 0 | **47.9** | 5,880 | 0 |
| 47 | 190 | 2.17% | -60 | -174 | 40 | 7,600 | 44.0 | **59.0** | 7,600 | 0 | 0 | 0 | **49.0** | 7,600 | 0 |
| 48 | 191 | 2.18% | -40 | -145 | 40 | 7,640 | 45.1 | **60.1** | 7,640 | 0 | 0 | 0 | **50.1** | 7,640 | 0 |
| 49 | 265 | 3.03% | -20 | -116 | 40 | 10,600 | 45.8 | **60.8** | 10,600 | 0 | 0 | 0 | **50.8** | 10,600 | 0 |
| 50 | 267 | 3.05% | 0 | -88 | 40 | 10,680 | 46.6 | 61.6 | 0 | 10,680 | 0 | 10,680 | **51.6** | 10,680 | 0 |
| 51 | 363 | 4.14% | 20 | -59 | 40 | 14,520 | 47.7 | 62.7 | 0 | 14,520 | 0 | 14,520 | **52.7** | 14,520 | 0 |
| 52 | 384 | 4.38% | 40 | -30 | 40 | 15,360 | 48.3 | 63.3 | 0 | 15,360 | 0 | 15,360 | **53.3** | 15,360 | 0 |
| 53 | 435 | 4.97% | 60 | -1 | 40 | 17,400 | 49.4 | 64.4 | 0 | 17,400 | 0 | 17,400 | **54.4** | 17,400 | 0 |
| 54 | 427 | 4.87% | 80 | 28 | 54 | 22,951 | 50.4 | 65.4 | 0 | 22,951 | 0 | 22,951 | **55.4** | 22,951 | 0 |
| 55 | 455 | 5.19% | 100 | 56 | 78 | 35,547 | 51.2 | 66.2 | 0 | 35,547 | 37 | 18,576 | **56.2** | 35,547 | -16,971 |
| 56 | 504 | 5.75% | 120 | 85 | 103 | 51,660 | 52.2 | 67.2 | 0 | 51,660 | 49 | 26,997 | **57.2** | 51,660 | -24,663 |
| 57 | 475 | 5.42% | 140 | 114 | 127 | 60,266 | 53.2 | 68.2 | 0 | 60,266 | 61 | 31,494 | 58.2 | 0 | 31,494 |
| 58 | 539 | 6.15% | 160 | 143 | 151 | 81,524 | 53.7 | 68.7 | 0 | 81,524 | 72 | 42,603 | 58.7 | 0 | 42,603 |
| 59 | 455 | 5.19% | 180 | 171 | 176 | 79,909 | 54.3 | 69.3 | 0 | 79,909 | 84 | 41,759 | 59.3 | 0 | 41,759 |
| 60 | 432 | 4.93% | 200 | 200 | 200 | 86,400 | 55.2 | 70.2 | 0 | 86,400 | 95 | 45,151 | 60.2 | 0 | 45,151 |
| 61 | 343 | 3.92% | 220 | 229 | 224 | 76,961 | 55.6 | 70.6 | 0 | 76,961 | 95 | 44,547 | 60.6 | 0 | 44,547 |
| 62 | 309 | 3.53% | 240 | 258 | 249 | 76,864 | 56.4 | 71.4 | 0 | 76,864 | 88 | 49,749 | 61.4 | 0 | 49,749 |
| 63 | 210 | 2.40% | 260 | 286 | 273 | 57,356 | 56.8 | 71.8 | 0 | 57,356 | 81 | 40,346 | 61.8 | 0 | 40,346 |
| 64 | 234 | 2.67% | 280 | 315 | 298 | 69,615 | 57.5 | 72.5 | 0 | 69,615 | 74 | 52,241 | 62.5 | 0 | 52,241 |
| 65 | 230 | 2.63% | 300 | 344 | 322 | 74,031 | 57.9 | 72.9 | 0 | 74,031 | 68 | 58,506 | 62.9 | 0 | 58,506 |
| 66 | 159 | 1.82% | 320 | 373 | 346 | 55,054 | 58.8 | 73.8 | 0 | 55,054 | 61 | 45,395 | 63.8 | 0 | 45,395 |
| 67 | 174 | 1.99% | 340 | 401 | 371 | 64,489 | 59.1 | 74.1 | 0 | 64,489 | 54 | 55,093 | 64.1 | 0 | 55,093 |
| 68 | 133 | 1.52% | 360 | 420 | 390 | 51,870 | 59.8 | 74.8 | 0 | 51,870 | 47 | 45,586 | 64.8 | 0 | 45,586 |
| 69 | 146 | 1.67% | 360 | 420 | 390 | 56,940 | 60.2 | 75.2 | 0 | 56,940 | 41 | 51,027 | 65.2 | 0 | 51,027 |
| 70 | 110 | 1.26% | 360 | 420 | 390 | 42,900 | 60.8 | 75.8 | 0 | 42,900 | 34 | 39,188 | 65.8 | 0 | 39,188 |
| 71 | 132 | 1.51% | 360 | 420 | 390 | 51,480 | 61.4 | 76.4 | 0 | 51,480 | 27 | 47,916 | 66.4 | 0 | 47,916 |
| 72 | 92 | 1.05% | 360 | 420 | 390 | 35,880 | 62.1 | 77.1 | 0 | 35,880 | 20 | 34,017 | 67.1 | 0 | 34,017 |
| 73 | 60 | 0.68% | 360 | 420 | 390 | 23,400 | 61.9 | 76.9 | 0 | 23,400 | 14 | 22,590 | 66.9 | 0 | 22,590 |
| 74 | 79 | 0.90% | 360 | 420 | 390 | 30,810 | 62.4 | 77.4 | 0 | 30,810 | 7 | 30,277 | 67.4 | 0 | 30,277 |
| 75 | 38 | 0.43% | 360 | 420 | 390 | 14,820 | 61.9 | 76.9 | 0 | 14,820 | 0 | 14,820 | 66.9 | 0 | 14,820 |
| 76 | 33 | 0.38% | 360 | 420 | 390 | 12,870 | 61.8 | 76.8 | 0 | 12,870 | 0 | 12,870 | 66.8 | 0 | 12,870 |
| 77 | 23 | 0.26% | 360 | 420 | 390 | 8,970 | 61.5 | 76.5 | 0 | 8,970 | 0 | 8,970 | 66.5 | 0 | 8,970 |
| 78 | 26 | 0.30% | 360 | 420 | 390 | 10,140 | 61.6 | 76.6 | 0 | 10,140 | 0 | 10,140 | 66.6 | 0 | 10,140 |
| 79 | 12 | 0.14% | 360 | 420 | 390 | 4,680 | 62.8 | 77.8 | 0 | 4,680 | 0 | 4,680 | 67.8 | 0 | 4,680 |
| 80 | 18 | 0.21% | 360 | 420 | 390 | 7,020 | 62.5 | 77.5 | 0 | 7,020 | 0 | 7,020 | 67.5 | 0 | 7,020 |
| 81 | 11 | 0.13% | 360 | 420 | 390 | 4,290 | 62.8 | 77.8 | 0 | 4,290 | 0 | 4,290 | 67.8 | 0 | 4,290 |
| 82 | 16 | 0.18% | 360 | 420 | 390 | 6,240 | 63.5 | 78.5 | 0 | 6,240 | 0 | 6,240 | 68.5 | 0 | 6,240 |
| 83 | 11 | 0.13% | 360 | 420 | 390 | 4,290 | 63.4 | 78.4 | 0 | 4,290 | 0 | 4,290 | 68.4 | 0 | 4,290 |
| 84 | 11 | 0.13% | 360 | 420 | 390 | 4,290 | 63.6 | 78.6 | 0 | 4,290 | 0 | 4,290 | 68.6 | 0 | 4,290 |
| 85 | 5 | 0.06% | 360 | 420 | 390 | 1,950 | 63.6 | 78.6 | 0 | 1,950 | 0 | 1,950 | 68.6 | 0 | 1,950 |
| 86 | 5 | 0.06% | 360 | 420 | 390 | 1,950 | 63.4 | 78.4 | 0 | 1,950 | 0 | 1,950 | 68.4 | 0 | 1,950 |
| 87 | 8 | 0.09% | 360 | 420 | 390 | 3,120 | 64.3 | 79.3 | 0 | 3,120 | 0 | 3,120 | 69.3 | 0 | 3,120 |
| 88 | 7 | 0.08% | 360 | 420 | 390 | 2,730 | 65.7 | 80.7 | 0 | 2,730 | 0 | 2,730 | 70.7 | 0 | 2,730 |
| 89 | 6 | 0.07% | 360 | 420 | 390 | 2,340 | 64.7 | 79.7 | 0 | 2,340 | 0 | 2,340 | 69.7 | 0 | 2,340 |
| 90 | 2 | 0.02% | 360 | 420 | 390 | 780 | 65.5 | 80.5 | 0 | 780 | 0 | 780 | 70.5 | 0 | 780 |
| Totals: | 8760 | | | | | 1,389,586 | | | | 1,334,346 | | 994,447 | | | 826,329 |

## SUMMARY

| | |
|---|---|
| Existing Free Cooling Activation Temp | 49 Degrees F |
| Proposed Free Cooling Activation Temp | 56 Degrees F |
| Total Hours of Cooling | 8,659 Hours |
| Existing Free Cooling Hours of Operation | 1,280 Hours |
| Proposed Free Cooling Hours of Operation | 4,115 Hours |
| al Ton-hours of chiller cooling without economizer and with existing free cooling control | 1,334,346 Ton-hours |
| Total Ton-hours of Chiller Cooling with economizer and existing free cooling | 994,447 Ton-hours |
| Total Ton-hours of Chiller Cooling with economizer and new free cooling operation | 826,329 Ton-hours |

Note: Bold data in the table indicates condenser water temperatures at which free cooling operates under the existing and the proposed conditions

# Economizer Operation Binned Weather Analysis

| OA Temp | Hours | Total Tonnage for Building (based on measured data) | Tonnage Requirements for AC-1 (based on estimated percent of total building load) | CFM Required to Meet Load | Maximum CFM Through Economizer | Maximum Tonnage Available with OA | Useful Economizer Tons (Chiller Tonnage Reduction) | Average Power Reduction (kW) | Average Energy Savings (kWh/yr) |
|---|---|---|---|---|---|---|---|---|---|
| 55 | 455 | 78 | 37 | 20,721 | 75,000 | 135 | 37 | 22 | 9,843 |
| 56 | 504 | 103 | 49 | 27,186 | 75,000 | 128 | 49 | 28 | 14,305 |
| 57 | 475 | 127 | 61 | 33,651 | 75,000 | 122 | 61 | 35 | 16,688 |
| 58 | 539 | 151 | 72 | 40,116 | 75,000 | 115 | 72 | 42 | 22,574 |
| 59 | 455 | 176 | 84 | 46,582 | 75,000 | 108 | 84 | 49 | 22,127 |
| 60 | 432 | 200 | 95 | 53,047 | 75,000 | 101 | 95 | 55 | 23,924 |
| 61 | 343 | 224 | 107 | 59,512 | 75,000 | 95 | 95 | 55 | 18,800 |
| 62 | 309 | 249 | 119 | 65,977 | 75,000 | 88 | 88 | 51 | 15,727 |
| 63 | 210 | 273 | 130 | 72,442 | 75,000 | 81 | 81 | 47 | 9,866 |
| 64 | 234 | 298 | 142 | 78,907 | 75,000 | 74 | 74 | 43 | 10,077 |
| 65 | 230 | 322 | 154 | 85,372 | 75,000 | 68 | 68 | 39 | 9,005 |
| 66 | 159 | 346 | 165 | 91,837 | 75,000 | 61 | 61 | 35 | 5,602 |
| 67 | 174 | 371 | 177 | 98,302 | 75,000 | 54 | 54 | 31 | 5,450 |
| 68 | 133 | 390 | 186 | 103,441 | 75,000 | 47 | 47 | 27 | 3,645 |
| 69 | 146 | 390 | 186 | 103,441 | 75,000 | 41 | 41 | 23 | 3,430 |
| 70 | 110 | 390 | 186 | 103,441 | 75,000 | 34 | 34 | 20 | 2,153 |
| 71 | 132 | 390 | 186 | 103,441 | 75,000 | 27 | 27 | 16 | 2,067 |
| 72 | 92 | 390 | 186 | 103,441 | 75,000 | 20 | 20 | 12 | 1,081 |
| 73 | 60 | 390 | 186 | 103,441 | 75,000 | 14 | 14 | 8 | 470 |
| 74 | 79 | 390 | 186 | 103,441 | 75,000 | 7 | 7 | 4 | 309 |
| 75 | 38 | 390 | 186 | 103,441 | 75,000 | 0 | 0 | 0 | 0 |
| Totals: | 5,309 | | | | | | | | 197,142 |

| Assumptions | | |
|---|---|---|
| Percent of Building Cooling Used by AC-1* | 48% | |
| Facility Balance Point | 50 | Degrees F |
| Average Supply Air Temp. | 55 | Degrees F |
| Average Return Air Temp. | 75 | Degrees F |
| Existing OSA Volume | 10,000 | CFM |
| Annual Average Supply Air | 75,000 | CFM |
| Change in OSA Volume | 65,000 | CFM |
| Average Chiller Efficiency | 0.58 | kW/ton |

*Notes:*

* Calculated based upon design chilled water flow rates.

Below 55 degrees F, the economizer still saves energy, but it is not as effective, because the demand has declined and air temps are too cold. We have omitted these additional savings to remain conservative.

# Hyatt Regency Energy Saving Measures

***Measure 2: Correct Chilled Water Reset Control***

**End Use: Chillers**

| | | |
|---|---|---|
| Desired Chilled Water Reset Low (OAT/CHWST) | 62/52 *Deg. F/Deg. F* | Control logic |
| Desired Chilled Water Reset High (OAT/CHWST) | 72/42 *Deg. F/Deg. F* | Control logic |
| Chiller 1 Actual Chilled Water Reset Low (OAT/CHWST) | 62/42 *Deg. F/Deg. F* | Measured |
| Chiller 1 Actual Chilled Water Reset High (OAT/CHWST) | 72/42 *Deg. F/Deg. F* | Measured |
| Chiller 2 Actual Chilled Water Reset Low (OAT/CHWST) | 62/46 *Deg. F/Deg. F* | Measured |
| Chiller 2 Actual Chilled Water Reset High (OAT/CHWST) | 72/42 *Deg. F/Deg. F* | Measured |
| Existing Chiller Energy Use | 426,551 *kWh/yr* | Based on condenser water analysis - measure 1 |
| Annual Energy Savings Correcting OAT Control | 13,326 *kWh/yr* | Annualized binned weather analysis - see attached |
| Proposed Chiller Energy Use Correcting OAT Control | 413,225 *kWh/yr* | |
| Existing Peak Period Demand | 249 *kW* | From measure 1 |
| Peak Demand Savings | 0 *kW* | Reset is operating correctly at peak loads (OAT > 72) |
| Average Cost of Electricity | $0.08 *per kWh* | |
| Total Annual Savings | $1,066 *per year* | |
| Cost to Modify Control Logic | $2,000 | |

**Measure Description**

Increasing the CHWST by 1 degree F typically improves the chiller's efficiency by 1.2%. The current JC control system attempts to employ a chilled water reset strategy which simply increasing the CHWST linearly based on OAT. Our measured data show that the CHWST drops considerably lower than the setpoint based solely on OAT. This calculation assumes that both chillers are controlled based on the same new reset strategy.

# Chilled Water Reset Binned Weather Analysis

| OA Temp | Hours | Percent | Chiller 1 Tons (based on measured data and regression) | Chiller 2 Tons (based on measured data and regression) | Reduced Tons Adjusting for Economizer (from economizer analysis) | Design Reset Temperature | Actual Chiller 1 Reset Temperature | Actual Chiller 2 Reset Temperature |
|---|---|---|---|---|---|---|---|---|
| 31 | 1 | 0.01% | -380 | -634 | 0 | 83.0 | 42.0 | 59.1 |
| 32 | 4 | 0.05% | -360 | -605 | 0 | 82.0 | 42.0 | 58.7 |
| 33 | 7 | 0.08% | -340 | -576 | 0 | 81.0 | 42.0 | 58.3 |
| 34 | 8 | 0.09% | -320 | -548 | 0 | 80.0 | 42.0 | 57.8 |
| 35 | 7 | 0.08% | -300 | -519 | 0 | 79.0 | 42.0 | 57.4 |
| 36 | 16 | 0.18% | -280 | -490 | 0 | 78.0 | 42.0 | 57.0 |
| 37 | 13 | 0.15% | -260 | -461 | 0 | 77.0 | 42.0 | 56.6 |
| 38 | 18 | 0.21% | -240 | -433 | 0 | 76.0 | 42.0 | 56.2 |
| 39 | 27 | 0.31% | -220 | -404 | 0 | 75.0 | 42.0 | 55.8 |
| 40 | 52 | 0.59% | -200 | -375 | 0 | 74.0 | 42.0 | 55.3 |
| 41 | 46 | 0.53% | -180 | -346 | 0 | 73.0 | 42.0 | 54.9 |
| 42 | 66 | 0.75% | -160 | -318 | 0 | 72.0 | 42.0 | 54.5 |
| 43 | 82 | 0.94% | -140 | -289 | 0 | 71.0 | 42.0 | 54.1 |
| 44 | 120 | 1.37% | -120 | -260 | 0 | 70.0 | 42.0 | 53.7 |
| 45 | 121 | 1.38% | -100 | -231 | 0 | 69.0 | 42.0 | 53.3 |
| 46 | 147 | 1.68% | -80 | -203 | 0 | 68.0 | 42.0 | 52.8 |
| 47 | 190 | 2.17% | -60 | -174 | 0 | 67.0 | 42.0 | 52.4 |
| 48 | 191 | 2.18% | -40 | -145 | 0 | 66.0 | 42.0 | 52.0 |
| 49 | 265 | 3.03% | -20 | -116 | 0 | 65.0 | 42 0 | 51.6 |
| 50 | 267 | 3.05% | 0 | -88 | 0 | 64.0 | 42 0 | 51 2 |
| 51 | 363 | 4.14% | 20 | -59 | 0 | 63.0 | 42.0 | 50.8 |
| 52 | 384 | 4.38% | 40 | -30 | 0 | 62.0 | 42.0 | 50.3 |
| 53 | 435 | 4.97% | 60 | -1 | 0 | 61.0 | 42.0 | 49 9 |
| 54 | 427 | 4.87% | 80 | 28 | 0 | 60.0 | 42.0 | 49.5 |
| 55 | 455 | 5.19% | 100 | 56 | 37 | 59.0 | 42.0 | 49.1 |
| 56 | 504 | 5.75% | 120 | 85 | 49 | 58.0 | 42.0 | 48.7 |
| 57 | 475 | 5.42% | 140 | 114 | 61 | 57.0 | 42.0 | 48.3 |
| 58 | 539 | 6.15% | 160 | 143 | 72 | 56.0 | 42.0 | 47.8 |
| 59 | 455 | 5.19% | 180 | 171 | 84 | 55.0 | 42.0 | 47.4 |
| 60 | 432 | 4.93% | 200 | 200 | 95 | 54.0 | 42.0 | 47.0 |
| 61 | 343 | 3.92% | 220 | 229 | 95 | 53.0 | 42.0 | 46.6 |
| 62 | 309 | 3.53% | 240 | 258 | 88 | 52.0 | 42.0 | 46.2 |
| 63 | 210 | 2.40% | 260 | 286 | 81 | 51.0 | 42.0 | 45.8 |
| 64 | 234 | 2.67% | 280 | 315 | 74 | 50.0 | 42.0 | 45.3 |
| 65 | 230 | 2.63% | 300 | 344 | 68 | 49.0 | 42.0 | 44.9 |
| 66 | 159 | 1.82% | 320 | 373 | 61 | 48.0 | 42.0 | 44.5 |
| 67 | 174 | 1.99% | 340 | 401 | 54 | 47.0 | 42.0 | 44.1 |
| 68 | 133 | 1.52% | 360 | 420 | 47 | 46 0 | 42.0 | 43.7 |
| 69 | 146 | 1.67% | 360 | 420 | 41 | 45 0 | 42.0 | 43.3 |
| 70 | 110 | 1.26% | 360 | 420 | 34 | 44 0 | 42.0 | 42.8 |
| 71 | 132 | 1.51% | 360 | 420 | 27 | 43.0 | 42.0 | 42.4 |
| 72 | 92 | 1.05% | 360 | 420 | 20 | 42.0 | 42.0 | 42.0 |
| 73 | 60 | 0.68% | 360 | 420 | 14 | 41.0 | 42.0 | 41.6 |
| 74 | 79 | 0.90% | 360 | 420 | 7 | 40.0 | 42.0 | 41.2 |
| 75 | 38 | 0.43% | 360 | 420 | 0 | 39.0 | 42.0 | 40 8 |
| 76 | 33 | 0.38% | 360 | 420 | 0 | 38.0 | 42.0 | 40.3 |
| 77 | 23 | 0.26% | 360 | 420 | 0 | 37.0 | 42.0 | 39.9 |
| 78 | 26 | 0.30% | 360 | 420 | 0 | 36.0 | 42.0 | 39.5 |
| 79 | 12 | 0.14% | 360 | 420 | 0 | 35.0 | 42.0 | 39.1 |
| 80 | 18 | 0.21% | 360 | 420 | 0 | 34.0 | 42.0 | 38.7 |
| 81 | 11 | 0.13% | 360 | 420 | 0 | 33.0 | 42.0 | 38.3 |
| 82 | 16 | 0.18% | 360 | 420 | 0 | 32.0 | 42.0 | 37.8 |
| 83 | 11 | 0.13% | 360 | 420 | 0 | 31.0 | 42.0 | 37.4 |
| 84 | 11 | 0.13% | 360 | 420 | 0 | 30.0 | 42.0 | 37.0 |
| 85 | 5 | 0.06% | 360 | 420 | 0 | 29.0 | 42.0 | 36.6 |
| 86 | 5 | 0.06% | 360 | 420 | 0 | 28.0 | 42.0 | 36.2 |
| 87 | 8 | 0.09% | 360 | 420 | 0 | 27.0 | 42.0 | 35.8 |
| 88 | 7 | 0.08% | 360 | 420 | 0 | 26.0 | 42.0 | 35.3 |
| 89 | 6 | 0.07% | 360 | 420 | 0 | 25.0 | 42.0 | 34.9 |
| 90 | 2 | 0.02% | 360 | 420 | 0 | 24.0 | 42.0 | 34.5 |
| Totals: | 8760 | | | | | | | |

## Chilled Water Reset Regressions

| Design Control CHWST Reset | | | |
|---|---|---|---|
| OAT | CHWST | Slope | Y-intercept |
| 72 | 42 | -1.00 | 114 |
| 62 | 52 | | |
| 10 | -10 | | |

| Actual Control CHWST Reset | | | |
|---|---|---|---|
| OAT | CHWST | Slope | Y-intercept |
| 72 | 42 | -0.42 | 72 |
| 60 | 47 | | |
| 12 | -5 | | |

| Chiller 1 | | Chiller 2 | | | | | |
|---|---|---|---|---|---|---|---|
| Delta T | % Eff. Gain* | Delta T | % Eff. Gain* | Avg. Eff. Gain | Avg. Chiller kW* | Avg. kW Savings | Savings (kWh/yr) |
| 10.0 | 12.0% | 5.8 | 7.0% | 9.5% | 84 | 7.95 | 2,458 |
| 9.0 | 10.8% | 5.3 | 6.3% | 8.6% | 100 | 8.54 | 1,794 |
| 8.0 | 9.6% | 4.7 | 5.6% | 7.6% | 116 | 8.82 | 2,065 |
| 7.0 | 8.4% | 4.1 | 4.9% | 6.7% | 132 | 8.80 | 2,023 |
| 6.0 | 7.2% | 3 5 | 4.2% | 5.7% | 148 | 8.46 | 1,345 |
| 5 0 | 6.0% | 2.9 | 3.5% | 4.8% | 165 | 7.82 | 1,361 |
| 4.0 | 4.8% | 2.3 | 2.8% | 3.8% | 178 | 6.77 | 901 |
| 3.0 | 3.6% | 1.8 | 2.1% | 2.9% | 182 | 5.18 | 756 |
| 2.0 | 2.4% | 1.2 | 1.4% | 1.9% | 185 | 3.52 | 387 |
| 1.0 | 1.2% | 0.6 | 0.7% | 1.0% | 189 | 1.79 | 237 |
| 0.0 | 0.0% | 0.0 | 0.0% | 0.0% | 192 | 0.00 | 0 |
| | | | | | | Total kWh/yr: | 13,326 |

** Notes:*

"% Eff. Gain": We assume that each degree increase in chilled water supply temperature results in 1.2% increase in chiller efficiency (lower kW/ton) based upon past experience with similar systems.

"Avg. Chiller kW": Based upon improved chiller efficiency (0.52 kW/ton) with new tower and economizer controls.

# Hyatt Regency Energy Saving Measures

### *Measure 3: Trim the Impellers on the Chilled Water Pumps and Replace the Water Bypass Valve with a Motorized Valve*

***End Use: Chilled Water Pumps***

| | | |
|---|---|---|
| Current Average Pressure Drop at 70 psi Bypass Control During Chiller Cooling | 124 *feet w.g.* | Measured |
| Current Average Pressure Drop at 70 psi Bypass Control During Free Cooling | 144 *feet w.g.* | Estimated |
| Average Pressure Drop with New Bypass Control During Chiller Cooling | 140 *feet w.g.* | Estimated |
| Average Pressure Drop with New Bypass Control During Free Cooling | 160 *feet w.g.* | Estimated |
| Current Average Chilled Water Flow | 1,300 *GPM* | Measured |
| Average Chilled Water Flow with New Bypass Control and Impeller Length | 930 *GPM* | To bring system back to the design flow |
| Pump Efficiency at Existing Conditions During Chiller Operation | 70% | From manufacturer's specs |
| Pump Efficiency at Existing Conditions During Free Cooling Operation | 72% | From manufacturer's specs |
| Pump Efficiency at Proposed Conditions During Chiller Cooling | 77% | From manufacturer's specs |
| Pump Efficiency at Proposed Conditions During Free Cooling | 77% | From manufacturer's specs |
| Shaft Power Reduction During Chiller Operation | 15.3 *hp* | Pump formula (verified with pump curve) |
| Shaft Power Reduction During Free Cooling | 17.1 *hp* | Pump formula (verified with pump curve) |
| Motor Efficiency | 85% | Estimated based upon design specs |
| Input Power Reduction During Chiller Operation | 13.5 *kW* | |
| Input Power Reduction During Free Cooling | 15.0 *kW* | |
| Existing Pump Demand During Chiller Cooling | 48.1 *kW* | Measured (essentially constant at all loads) |
| Existing Pump Demand During Free Cooling | 54.9 *kW* | Estimated from manufacturer's specs |
| Proposed Pump Peak Demand | 34.6 *kW* | Peak operation involves chiller cooling, not free cooling |
| Proposed Pump Demand During Free Cooling | 39.9 *kW* | |
| Total Hours of Pump Operation (Chiller and Free Cooling) | 8,659 *hrs/yr* | From measure 1 analysis |
| Existing Annual Hours of Free Cooling Operation | 1,280 *hrs/yr* | From measure 1 analysis |
| Proposed Annual Hours of Free Cooling Operation | 4,115 *hrs/yr* | Based on improved free cooling from measure 1 |
| Existing Pump Energy Use | 416,498 *kWh/yr* | |
| Proposed Pump Energy Use | 321,520 *kWh/yr* | |
| Annual Energy Savings | 94,978 *kWh/yr* | |
| Average Cost of Electricity | $0.08 *per kWh* | |
| Annual Cost Savings | $7,598 *per year* | Not including peak demand savings |
| Cost of Trimming both Impellers and Replacing the Bypass Valve | $13,000 | |

**Measure Description:** The chilled water pumps are overpumping the chillers. Rather than closing valves and introducing pressure drop into the system, the impellers should be trimmed to reduce the flow. The manufacturer's data shows that this not only reduces power output, it also increases pump efficiency.

The current bypass valve employs a constant setting for pressure control which was factory set at 70 psi. However, the building normally operates at about 85 psi at the point where the pressure measurement is taken - causing the valve to remain open most of the time. The valve should be replace with a motorized valve controlled based on a remote pressure reading. The pressure reading should be taken at least 2/3 downstream along the longest pipe run to insure that the longer runs are not starved when the bypass valve is opened. Due to this remote reading, a connection to the control system will be best to relay the desired valve position to the valve actuator.

# Hyatt Regency Energy Saving Measures

## Measure 4: Re-pipe Heat Exchanger Chilled Water Supply

**End Use: Chilled Water Pumps**

| | | |
|---|---|---|
| Existing System Pressure Drop in Chiller Operation | 140 *feet w.g.* | Assumed based on changes from measure 3 |
| Existing Pressure Drop In Free Cooling Operation | 160 *feet w.g.* | Estimated based on flow data and heat exchanger specifications |
| Pressure Drop Across Chillers | 20 *feet w.g.* | Measured (amount of reduction possible with measure) |
| Proposed Pressure Drop in Free Cooling Operation | 140 *feet w.g.* | |
| Pump Efficiency at Existing Chiller Cooling Conditions | 77.2% | Based on measure 3 and manufacturer's specs |
| Pump Efficiency at Existing Free Cooling Conditions | 77.3% | Based on measure 3 and manufacturer's specs |
| Pump Efficiency at Proposed Free Cooling Conditions | 77.2% | From manufacturer's specs |
| Average Chilled Water Flow | 930 *GPM* | Assumed based on changes from measure 3 |
| Shaft Power Reduction During Free Cooling | 6.0 *hp* | Pump formula (verified with pump curve) |
| Motor Efficiency | 85% | Estimated based upon design specs |
| Input Power Reduction During Free Cooling | 5.3 *kW* | |
| Existing Pump Demand During Chiller Operation | 34.6 *kW* | Assumed based on changes from measure 3 |
| Existing Pump Demand During Free Cooling Operation | 39.9 *kW* | |
| Pump Peak Demand Reduction | 0.0 *kW* | The modifications result in off-peak operation changes |
| Proposed Pump Power During Free Cooling | 34.6 *kW* | |
| Total Hours of Pump Operation (Chiller and Free Cooling) | 8,659 *hrs/yr* | From measure 1 analysis |
| Annual Hours of Free Cooling Operation | 4,115 *hrs/yr* | Based on improved free cooling from measure 1 |
| Existing Total Pump Energy Use | 321,520 *kWh/yr* | From measure 3 |
| Proposed Total Pump Energy Use | 299,492 *kWh/yr* | |
| Annual Energy Savings | 22,028 *kWh/yr* | |
| Average Cost of Electricity | $0.08 *per kWh* | |
| Annual Cost Savings | $1,762 *per year* | Not including peak demand savings |
| Cost to Modify Chilled Water Supply Piping | $7,000 | Piping modification and 3 new pneumatic valves |

**Measure Description**

The heat exchanger was designed to operate in parallel with the chillers on both the chilled and condenser water sides. However, the piping to allow this on the chilled water side is not constructed to allow this. When combined with the changes from measures 3 and 12, this measure will maximize the system's ability to "free cool."

# Hyatt Regency Energy Saving Measures

***Measure 5: Use a Static Pressure Setpoint Reset for AC-1***

***End Use: Air Handler AC-1***

| | | |
|---|---|---|
| Current Supply Fan Static Pressure Setpoint | 1.4 *inches w.g.* | JC control system |
| Proposed Average Supply Fan Static Pressure Setpoint with New Reset Control | 1.2 *inches w.g.* | |
| Ratio Reduced Duct Static Pressure | 0.86 | |
| Ratio Reduced Supply Fan Power | 0.79 | Fan law savings |
| Peak Fan Power Reduction | 0 *kW* | The modifications result mostly in off-peak operation changes |
| Existing Average Fan Energy | 313,659 *kWh/yr* | From measure 6 |
| Proposed Average Fan Energy Use | 248,907 *kWh/yr* | |
| Total Fan Energy Savings | 64,752 *kWh/yr* | |

***End Use: Chillers***

| | | |
|---|---|---|
| Existing Average Total Fan Power | 36 *kW* | Measured |
| Proposed Average Total Fan Power with New Reset Control | 28 *kW* | |
| Existing Average Parasitic Fan Motor Heat Load on Chillers | 10.2 *tons* | |
| Proposed Average Parasitic Fan Motor Heat Load on Chillers | 8.1 *tons* | |
| Chiller Efficiency | 0.52 *kW/ton* | From measure 2 |
| Peak Demand Reduction | 0 *kW* | The modifications result mostly in off-peak operation changes |
| Annual Hours of Chiller Operation | 4,544 *hrs/yr* | Annualized binned analysis for measure 1 |
| Total Chiller Energy Use | 268,028 *kWh/yr* | From measure 6 |
| Existing Average Parasitic Fan Motor Load on Chillers | 24,063 *kWh/yr* | |
| Proposed Average Parasitic Fan Motor Load on Chillers | 19,095 *kWh/yr* | |
| Proposed Total Chiller Energy Use | 263,060 *kWh/yr* | |
| Total Chiller Energy Savings | 4,968 *kWh/yr* | |

| | | |
|---|---|---|
| Total Measure Energy Savings | 69,719 *kWh/yr* | |
| Average Cost of Electricity | $0.08 *per kWh* | |
| Annual Cost Savings | $5,578 *per year* | |
| Cost to Modify Fan Control and Sensors | $8,000 | |

***Measure Description***

The static pressure setpoint for AC-1 is 1.4". This setpoint is not necessary at all times. It should be slowly lowered until the most sensitive zones are identified. Then, a temperature sensor in the return duct from those zones can be used to reset the static pressure setpoint. This strategy greatly reduces the energy used by the fans.

# Hyatt Regency Energy Saving Measures

## Measure 6: Optimize the Operation of AC-1 Supply Fans

**End Use: Air Handler AC-1**

| | | |
|---|---|---|
| Number of Fans Normally Operating Simultaneously | 2 | |
| Proposed Number of Fans Normally Operating Simultaneously | 3 | |
| Average Fan Motor Power | 30 *kW* | Measured |
| Percent Savings | 5% | Assumed about 10% of cube law fan savings |
| Average Power Reduction | 3.3 *kW* | |
| Peak Fan Power Reduction | 0 *kW* | The modifications result mostly in off-peak operation changes |
| Existing Average Fan Energy | 331,874 *kWh/yr* | From measure 9 |
| Proposed Average Fan Energy | 313,659 *kWh/yr* | |
| Total Fan Energy Savings | 18,215 *kWh/yr* | |

**End Use: Chillers**

| | | |
|---|---|---|
| Chiller Efficiency | 0.52 *kW/ton* | From measure 2 |
| Peak Chiller Demand Reduction | 0 *kW* | The modifications result mostly in off-peak operation changes |
| Annual Hours of Chiller Operation | 4,544 *hrs/yr* | Annualized binned analysis for measure 1 |
| Total Chiller Energy Use | 270,241 *kWh/yr* | From measure 9 |
| Existing Average Parasitic Fan Motor Load on Chillers | 40,322 *kWh/yr* | |
| Proposed Average Parasitic Fan Motor Load on Chillers | 38,109 *kWh/yr* | |
| Proposed Total Chiller Energy Use | 268,028 *kWh/yr* | |
| Total Chiller Energy Savings | 2,213 *kWh/yr* | |

| | | |
|---|---|---|
| Total Measure Energy Savings | 20,428 *kWh/yr* | |
| Average Cost of Electricity | $0.08 *per kWh* | |
| Annual Cost Savings | $1,634 *per year* | |
| Cost of Changing VFD Control Logic | $3,000 | |

**Measure Description**

The supply fans in AC-1 are controlled in stages to maintain a duct static pressure leading to operation dominated by only two fans. Since the power consumed by a fan increases with the cube of the air flow, operating all three fans at low speed will be more efficient than operating two at a higher speed. The motors are in the airstream, so parasitic losses are also reduced. The fans are currently on VFDs, so this modification can be easily implemented.

# Hyatt Regency Energy Saving Measures

### Measure 7: Implement Economizer Cycle in AC-1 and, if Necessary, Add Booster Fans to Outside Air Intake

**End Use: Chillers**

| | | |
|---|---|---|
| Specified Minimum Outside Air Volume | 57,000 *CFM* | From drawings |
| Existing Minimum Outside Air Volume | 10,000 *CFM* | Assumed based on fixed damper position |
| Maximum Total Air Delivered by AC-1 | 146,000 *CFM* | From drawings |
| Average Total Air Delivered by AC-1 | 75,000 *CFM* | Assumed (higher during day, lower at night) |
| Current Facility Outside Air Temperature Balance Point | 50 *Degrees F* | Temperature below which no cooling is required |
| Assumed Annual Average Return Air Temperature | 75 *Degrees F* | After modification to VAV boxes in meeting rooms and conference |
| Chiller 2 Efficiency at Existing CWST of 78 F | 0.58 *kW/ton* | Measured (conservative assumption - chiller 1 is not more efficient) |
| Existing Total Chiller Energy Use | 773,921 *kWh/yr* | Based on bin weather analysis - see attached |
| Potential Energy Savings | 197,142 *kWh/yr* | Based on economizer analysis - see attached |
| Proposed Total Chiller Energy Use | 576,779 *kWh/yr* | |
| Existing Peak Period Demand | 279 *kW* | Single chiller at max. capacity (465 tons) |
| Peak Demand Reduction | 0 *kW* | The modifications result in only off-peak operation changes |
| Average Cost of Electricity | $0.08 *per kWh* | |
| Annual Cost Savings | $15,771 *per year* | Not including peak demand savings |
| Measure Cost | $40,000 | $10,000 for dampers, etc. + $5,000 each for 6 booster fans |

**Measure Description**

Inspection revealed that the economizer damper is stuck in a mostly closed position. In this climate, the psychrometric conditions of the outside air are often suitable for direct space cooling, and the stuck damper prevents the unit from taking advantage of nature's free gift. The economizer dampers should be fixed to let in the maximum volume of outside air when the outside air is cooler than the return air. When the outside air is warmer than the return air, the economizer damper should be set to take in the minimum quantity of outside air to satisfy the occupancy requirements. In conjunction with this measure, the exhaust fans in the atrium will need to be controlled to maintain a stable static pressure in the building.

# Hyatt Regency Energy Saving Measures

***Measure 8: Modify Ballroom and Meeting Room VAV Boxes to Reduce Excess Cooling***

**End Use: Air Handler AC-1**

| | | |
|---|---|---|
| Current VAV Box Minimum Position | 50% | VAV box supplier's data |
| Total CFM in All AC-1 VAV Boxes at Current Minimum | 90,000 *CFM* | 50% of max CFM for all VAV boxes on AC-1 (estimated) |
| Total CFM in Ballroom and Meeting Rooms at Current Minimum | 47,000 *CFM* | 50% of max CFM for all VAV boxes in ballrooms and meeting |
| Proposed VAV Box Minimum Position During **Occupied Hours (6 am to 12 midnight)** | 20% | |
| Proposed VAV Box Minimum Position During **Unoccupied Hours (12 midnight to 6 am)** | 0% | |
| Total CFM New Minimum (occupied hours) | 36,000 *CFM* | All AC-1 VAV boxes running at 20% |
| Total CFM New Minimum (unoccupied hours) | 25,800 *CFM* | CFM of non-ballroom and non-meeting room areas only |
| Current Average Fan Supply CFM (occupied and unoccupied hours) | 110,000 *CFM* | Estimated |
| Average Fan Motor Power | 30 *kW* | Measured |
| Number of Fans Normally Operating Simultaneously During VAV Minimum Operation | 2 | |
| Proposed Hours of Operation at New Minimum Position (occupied hours) | 6 *hrs/day* | Estimated |
| Proposed Hours of Operation at Fully Closed Position (unoccupied hours) | 6 *hrs/day* | |
| Annual Total Hours of 2 Fan Use | 6,132 *hrs/yr* | Estimated |
| Existing Total Average Fan Energy | 604,440 *kWh/yr* | 2 and 3 fan operation |
| Existing Fan Energy Use at VAV Box Minimum Settings Before Control Modifications | 262,800 *kWh/yr* | |
| Proposed Fan Energy at VAV Box Minimum Settings After Control Modifications | 7,701 *kWh/yr* | |
| Proposed Total Average Fan Energy | 349,341 *kWh/yr* | |
| Total Fan Energy Savings | 255,099 *kWh/yr* | |
| Peak AC-1 Fan Power | 168 *kW* | All 3 fans at 60 hz |
| Peak AC-1 Fan Demand Reduction | 0 *kW* | The modifications result mostly in off-peak operation changes |

**End Use: Chillers**

| | | |
|---|---|---|
| Average Supply Air Delta T | 10 *Degrees F* | Measured |
| Existing Chiller Capacity Dedicated to These Spaces During Minimum and Unoccupied Hours | 394,200 *ton-hrs/yr* | |
| Proposed Chiller Capacity Dedicated to These Spaces During Minimum and Unoccupied Hours | 121,808 *ton-hrs/yr* | |
| Chiller #2 Efficiency | 0.52 *kW/ton* | From measure 1 after tower retrofit |
| Total Chiller Energy Use | 413,225 *kWh/yr* | From measure 2 |
| Existing Chiller Energy Dedicated to These Spaces During Minimum and Unoccupied Hours | 204,984 *kWh/yr* | |
| Proposed Chiller Energy Dedicated to These Spaces During Minimum and Unoccupied Hours | 63,340 *kWh/yr* | |
| Proposed Total Chiller Energy Use | 271,581 *kWh/yr* | |
| Total Chiller Energy Savings | 141,644 *kWh/yr* | |
| Peak Chiller Demand | 249 *kW* | From measure 2 |
| Peak Chiller Demand Reduction | 0 *kW* | The modifications result mostly in off-peak operation changes |

| | | |
|---|---|---|
| Total Measure Savings | 396,742 *kWh/yr* | |
| Average Cost of Electricity | $0.08 *per kWh* | |
| Annual Cost Savings | $31,739 *per year* | |
| Cost of VAV Box Control Modifications | $40,000 | Approximately $400 per box for 100 VAV boxes |

**Measure Description**

The minimum settings on the VAV boxes are currently 50% of the box maximum. In the meeting rooms and ballrooms, this results in considerable energy loss when the rooms are unoccupied or when cooling is not needed. Reset the box minimums to allow for a 20% minimum when cooling is not needed during normal hours and to completely close at night when the spaces are not in use. Savings from this simple change reverberate throughout the system, but only the most obvious savings are included in this calculation.

# Hyatt Regency Energy Saving Measures

*Measure 9: Remove Inlet Guide Vanes on AC-1 Supply Fans*

End Use: Air Handler AC-1

| | | |
|---|---|---|
| Air Handler Motor Size | 75 *hp* | |
| Average Motor Power (each) | 30 *kW* | Measured |
| Estimated Efficiency Gain | 5% | Manufacturer's data |
| Existing Peak Period Fan Power Demand | 168 *kW* | From measure 8 |
| Peak Period Fan Power Demand Reduction | 8.4 *kW* | |
| Proposed Peak Period Fan Power Demand | 159.5 *kW* | |
| Existing Average Fan Energy | 349,341 *kWh/yr* | From measure 8 |
| Proposed Average Fan Energy | 331,874 *kWh/yr* | |
| Total Fan Energy Savings | 17,467 *kWh/yr* | |

End Use: Chillers

| | | |
|---|---|---|
| Existing Average Total Fan Power | 39.9 *kW* | |
| Proposed Average Total Fan Power | 37.9 *kW* | |
| Existing Average Parasitic Fan Motor Heat Load on Chillers | 11.3 *tons* | |
| Proposed Average Parasitic Fan Motor Heat Load on Chillers | 10.8 *tons* | |
| Average Chiller Efficiency | 0.52 *kW/ton* | From measure 2 |
| Existing Peak Period Chiller Demand | 249 *kW* | From measure 8 |
| Peak Chiller Demand Reduction | 12.5 *kW* | |
| Proposed Peak Chiller Demand | 237 *kW* | |
| Annual Hours of Chiller Operation | 4,544 *hrs/yr* | Annualized binned analysis for measure 1 |
| Total Chiller Energy Use | 271,581 *kWh/yr* | From measure 8 |
| Existing Average Parasitic Fan Motor Load on Chillers | 26,800 *kWh/yr* | |
| Proposed Average Parasitic Fan Motor Load on Chillers | 25,460 *kWh/yr* | |
| Proposed Total Chiller Energy Use | 270,241 *kWh/yr* | |
| Total Chiller Energy Savings | 1,340 *kWh/yr* | |

| | | |
|---|---|---|
| Total Measure Energy Savings | 18,807 *kWh/yr* | |
| Average Cost of Electricity | $0.08 *per kWh* | |
| Annual Cost Savings | $1,505 *per year* | Not including peak demand savings |
| Cost of Removing Guide Vanes | $2,000 | |

Measure Description

**The supply fans in AC-1 originally used inlet vane control to maintain a constant static pressure for the variable air volume system. These fans were later retrofitted with VFDs, but the original inlet guide vanes were left in place. These vanes are no longer used and obstruct the air-flow into the fan even when the vanes are fully open. Removing the vanes will allow air to enter the fan more easily which can reduce the fan's power by 5%.**

**Installation of EMS (Site 2541)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | Installation of Energy Management System |
| Site Description | College/University |

**Measure Description** Install a fully integrated energy management system (EMS) to control the HVAC and lighting equipment on college campus.

**Summary of Ex Ante Impact Calculations** Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and plant usage characteristics.

**Comments on PG&E Calculations** The correct climate zone, building characteristics, plant type, and schedules were used in the application calculations.

**Evaluation Process** The evaluation process consists of a review of the application form and supporting documentation. After a thorough review of the application and replication of several of the impact calculations, an on-site audit was deemed unnecessary. Ex ante estimates are accepted as accurate.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 0 | 376,640 | 26,768 |
| **Adjusted Engineering** | 0 | 376,640 | 26,768 |
| **Engineering Realization Rate** | N/A | 1.00 | 1.00 |

**Chiller & Cooling Tower Replacement (Site 2542)**

| | |
|---|---|
| Program | Retrofit Efficiency Options Program |
| Measure | High Efficiency Water-Cooled Chiller and Oversized Cooling Tower |
| Site Description | College |

**Measure Description** Replace existing water-cooled chiller and cooling tower with a 350-ton high-efficiency water-cooled chiller and an oversized cooling tower.

**Summary of Ex Ante Impact Calculations** Tables of standard values were developed using the HBSSM simulation program based on climate zone, chiller size, building type, chiller efficiency, condenser water temperature, wet-bulb temperature, and cooling tower approach temperature. Values from these tables are used to calculate the rebate and associated impacts.

**Comments on PG&E Calculations** The application calculations used the correct business type, climate zone, chiller size, cooling tower approach temperature, chiller efficiency, and building size.

**Evaluation Process** The evaluation process consists of a review of the application form and supporting documentation, conducting an on-site survey and then computing impacts using the on-site data.

The on-site survey was conducted on August 10, 1999 in Fresno (Climate Zone 13). Information on the retrofit equipment and operating conditions was collected through an inspection of the chiller and through an interview with the Plant Engineer.

Discussions provided data for development of a relationship between chiller loading and outdoor dry bulb. The chiller is available from 6:00 am to 10:00 pm, including summer. The chiller is brought on line between 70 and 74 degrees F outside air temperature. The contact stated that the chiller is fully loaded at approximately 115 degrees F.

Models are calibrated with actual weather, observed chiller run hours since the installation, chiller loading under extreme outdoor temperature conditions, chilled water temperature, condenser water temperature, and cooling tower approach temperature. Energy impacts are based on typical weather data. A Title 24 baseline, nominal efficiency, and typical year bin weather data for the applicable climate zone are used in the bin analysis. To compute the impacts, the following assumptions were used:

- A linear loading strategy was used for the analysis of both the baseline and rebated chillers, which assumed initial loading at 70 degrees F and 100% loading at 115 degrees F.
- Based on a water-cooled screw chiller greater than 300 tons, a baseline Title 24 efficiency of 0.748 KW/ton was used.

Chiller efficiencies at various temperatures were calculated from updated default performance coefficients provided in a memo to the California Energy Commission titled "1995 Proposed Changes to the ACM Manual Central Plant Cooling Equipment" by Mark Hydeman. These coefficients were used to develop a chiller efficiency curve for the Rebate case and a Title 24 base case. Both evaluation-based energy and demand impacts were lower than Ex Ante estimates for the chiller, and for the cooling tower evaluation-based energy impacts were lower and demand impacts were higher than Ex Ante estimates. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

**Cooling Tower Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 30.8 | 168,590.89 | 0 |
| **Adjusted Engineering** | 42.66 | 36,861.25 | 0 |
| **Engineering Realization Rate** | 1.38 | 0.22 | N/A |

**Chiller Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 86.8 | 317,858.23 | 0 |
| **Adjusted Engineering** | 74.61 | 75,202.20 | 0 |
| **Engineering Realization Rate** | 0.86 | 0.24 | N/A |

Site 2542: Results

| Chiller Results | Energy | | Demand |
|---|---|---|---|
| | Savings | Impact | Impact |
| MDSS | | 317,858 | 86.8 |
| QC | 77,514 | 75,202 | 75 |
| Realization Rate | | 0.24 | 0.86 |

| Cooling Tower Results | Energy | | Demand |
|---|---|---|---|
| | Savings | Impact | Impact |
| MDSS | | 168,591 | 30.8 |
| QC | 35,119 | 36,861 | 43 |
| Realization Rate | | 0.22 | 1.38 |

| Pre-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.7 |
| Nom. Tons | 350 |
| nom kw | 245 |

| Post-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.486 |
| Nom. Tons | 350 |
| nom kw | 170.1 |

| Outdoor DB Temperature (F) | Operating Hours per year (Actual) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 112 | 0.00 | 350 | 0.624 | 0.00 | 0.00 |
| 107 | 30.00 | 341 | 0.584 | 5,978.20 | 199.27 |
| 102 | 100.00 | 298 | 0.583 | 17,331.82 | 173.32 |
| 97 | 184.00 | 254 | 0.586 | 27,380.05 | 148.80 |
| 92 | 303.00 | 210 | 0.599 | 38,100.16 | 125.74 |
| 87 | 325.00 | 166 | 0.626 | 33,846.73 | 104.14 |
| 82 | 379.00 | 123 | 0.686 | 31,842.14 | 84.02 |
| 77 | 404.00 | 79 | 0.830 | 26,409.26 | 65.37 |
| 72 | 338.00 | 35 | 1.377 | 16,295.69 | 48.21 |
| Totals | 2063.00 | | | 197,184.05 | 199.27 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 112 | 0.00 | 350 | 0.433 | 0.00 | 0.00 | 0.00 | 0.00 |
| 107 | 4.29 | 341 | 0.405 | 592.94 | 138.35 | 30.00 | 4,150.58 |
| 102 | 82.29 | 298 | 0.404 | 9,901.63 | 120.33 | 100.00 | 12,033.24 |
| 97 | 185.14 | 254 | 0.407 | 19,127.65 | 103.31 | 184.00 | 19,009.58 |
| 92 | 295.43 | 210 | 0.416 | 25,791.40 | 87.30 | 303.00 | 26,452.40 |
| 87 | 353.86 | 166 | 0.435 | 25,585.83 | 72.31 | 325.00 | 23,499.30 |
| 82 | 431.14 | 123 | 0.476 | 25,149.10 | 58.33 | 379.00 | 22,107.54 |
| 77 | 430.14 | 79 | 0.576 | 19,522.06 | 45.39 | 379.00 | 17,200.94 |
| 72 | 411.71 | 35 | 0.956 | 13,781.30 | 33.47 | 379.00 | 12,686.26 |
| Totals | 2,194.00 | | | 139,451.92 | 138.35 | 2,079.00 | 137,139.83 |

| Title 24 Baseline Chiller | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 350 |
| nom kw | 261.830 |

| Post-Retrofit Chiller w/ Coolong Tower | |
|---|---|
| Nom. Eff | 0.486 |
| Nom. Tons | 350 |
| nom kw | 170.1 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 112 | 0.00 | 350 | 0.667 | 0.00 | 0.00 |
| 107 | 4.29 | 341 | 0.624 | 912.69 | 212.96 |
| 102 | 82.29 | 298 | 0.623 | 15,241.29 | 185.22 |
| 97 | 185.14 | 254 | 0.627 | 29,442.61 | 159.03 |
| 92 | 295.43 | 210 | 0.640 | 39,699.92 | 134.38 |
| 87 | 353.86 | 166 | 0.669 | 39,383.50 | 111.30 |
| 82 | 431.14 | 123 | 0.733 | 38,711.25 | 89.79 |
| 77 | 430.14 | 79 | 0.887 | 30,049.72 | 69.86 |
| 72 | 411.71 | 35 | 1.472 | 21,213.14 | 51.52 |
| Totals | 2,194.00 | | | 214,654.12 | 212.96 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 112 | 0.00 | 350 | 0.308 | 0.00 | 0.00 | 0.00 | 0.00 |
| 107 | 4.29 | 341 | 0.280 | 410.13 | 95.70 | 30.00 | 2,870.89 |
| 102 | 82.29 | 298 | 0.279 | 6,841.63 | 83.14 | 100.00 | 8,314.49 |
| 97 | 185.14 | 254 | 0.282 | 13,255.15 | 71.59 | 184.00 | 13,173.33 |
| 92 | 295.43 | 210 | 0.291 | 18,036.40 | 61.05 | 303.00 | 18,498.65 |
| 87 | 353.86 | 166 | 0.310 | 18,232.24 | 51.52 | 325.00 | 16,745.39 |
| 82 | 431.14 | 123 | 0.351 | 18,547.22 | 43.02 | 379.00 | 16,304.10 |
| 77 | 430.14 | 79 | 0.451 | 15,287.85 | 35.54 | 404.00 | 14,358.69 |
| 72 | 411.71 | 35 | 0.831 | 11,980.05 | 29.10 | 404.00 | 11,755.58 |
| Totals | 2,194.00 | | 0.00 | 102,590.67 | 95.70 | 2,129.00 | 102,021.13 |

Site 2542: Inputs to Model

| Parameter | Value Reported | Units of Parameter | Notes |
|---|---|---|---|
| City | Fresno | | |
| Climate Zone | 13 | | |
| Pre-Retrofit Nominal Chiller Capacity | 350 | Tons | Application |
| Pre-Retrofit Nominal Chiller Efficiency | 0.7 | kW/ton | E Source |
| Pre-Retrofit Cooling Tower Approach Temperature | 16 | F | Contact provided estimate |
| | | | |
| Post-Retrofit Nominal Chiller Capacity | 350 | Tons | Application |
| Post-Retrofit Nominal Chiller Efficiency | 0.486 | kW/ton | From Chiller Rating Sheet |
| Post-Retrofit Cooling Tower Approach Temperature | 3.5 | F | Application |
| Baseline Chiller Efficiency | 0.748 | kW/ton | Title 24 Nominal Efficiency for Chiller > 300 Tons |
| | | | |
| Chiller AM Lockout | 6:00 | AM | Contact provided schedule; M-Sat |
| Chiller PM Lockout | 10:00 | PM | Contact provided schedule; M-F, 8pm on Sat |
| Chiller Startup OSA Temperature | 70 | F | Contact provided estimate |
| Chiller Max Load OSA Temperature | 110 | F | Contact provided estimate |
| Chilled Water Supply Temperature Setpoint | 46 | F | Contact provided setpoints; Chiller is on Manual Operation |
| Condenser Water Temperature | 76 | F | Contact provided setpoints; Chiller is on Manual Operation |
| Date of Chiller Installation | 6/21/97 | | Contact provided estimate |
| Date at Run Hour Reading | 8/10/99 | | Chiller Log |
| Number of Days Chiller Operated | 547 | days (M-F Only) | = ((Read Date - Install Date) * 5/7) - 10 Holidays |
| Run Hours for New Chiller | 3454 | hours | Documented from Chiller Log |
| Average Hours per Year of Chiller Operation | 1645.84 | Hours/Year (M-F Only) | = (Run Hours for New Chiller / Number of Days Chiller Operated) * 365 Days/Year * 5/7 |
| | | | |
| Predicted Run Hours Since Install Using Actual Weather & Setpoints | 4639.00 | hours | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |
| Predicted Hours per Year Using Actual Weather Data & Setpoints | 2063.00 | Hours/Year (M-F Only) | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |

Site 2542: Post-Retrofit Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.486 |
| Nom. Tons | 350 |
| nom kw | 170.1 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 350 | 82 | 48 | 353 | 1.000 | 1.00 | 0.89 | 0.1232 | 8.12 | 0.433 |
| 107 | 341 | 80.7 | 50.7 | 358 | 0.975 | 0.97 | 0.84 | 0.1153 | 8.67 | 0.405 |
| 102 | 298 | 80.0 | 50.0 | 358 | 0.850 | 0.84 | 0.84 | 0.1150 | 8.69 | 0.404 |
| 97 | 254 | 79.3 | 49.3 | 359 | 0.725 | 0.72 | 0.84 | 0.1158 | 8.64 | 0.407 |
| 92 | 210 | 78.7 | 48.7 | 359 | 0.600 | 0.61 | 0.84 | 0.1182 | 8.46 | 0.416 |
| 87 | 166 | 78.0 | 48.0 | 360 | 0.475 | 0.50 | 0.84 | 0.1237 | 8.08 | 0.435 |
| 82 | 123 | 77.3 | 47.3 | 360 | 0.350 | 0.41 | 0.84 | 0.1354 | 7.38 | 0.476 |
| 77 | 79 | 76.7 | 46.7 | 360 | 0.225 | 0.32 | 0.84 | 0.1639 | 6.10 | 0.576 |
| 72 | 35 | 76 | 46 | 360 | 0.100 | 0.23 | 0.85 | 0.2720 | 3.68 | 0.956 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2542: Baseline Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

Post-Retrofit Chiller

| | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 350 |
| nom kw | 261.829787 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 350 | 82 | 48 | 353 | 1.000 | 1.00 | 0.89 | 0.1897 | 5.27 | 0.667 |
| 107 | 341 | 80.7 | 50.7 | 358 | 0.975 | 0.97 | 0.84 | 0.1775 | 5.63 | 0.624 |
| 102 | 298 | 80.0 | 50.0 | 358 | 0.850 | 0.84 | 0.84 | 0.1771 | 5.65 | 0.623 |
| 97 | 254 | 79.3 | 49.3 | 359 | 0.725 | 0.72 | 0.84 | 0.1782 | 5.61 | 0.627 |
| 92 | 210 | 78.7 | 48.7 | 359 | 0.600 | 0.61 | 0.84 | 0.1820 | 5.49 | 0.640 |
| 87 | 166 | 78.0 | 48.0 | 360 | 0.475 | 0.50 | 0.84 | 0.1904 | 5.25 | 0.669 |
| 82 | 123 | 77.3 | 47.3 | 360 | 0.350 | 0.41 | 0.84 | 0.2085 | 4.80 | 0.733 |
| 77 | 79 | 76.7 | 46.7 | 360 | 0.225 | 0.32 | 0.84 | 0.2523 | 3.96 | 0.887 |
| 72 | 35 | 76 | 46 | 360 | 0.100 | 0.23 | 0.85 | 0.4187 | 2.39 | 1.472 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2542: Pre-Retrofit Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

Post-Retrofit Chiller

| | |
|---|---|
| Nom. Eff | 0.7 |
| Nom. Tons | 350 |
| nom kw | 245 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 350 | 82 | 48 | 353 | 1.000 | 1.00 | 0.89 | 0.1775 | 5.64 | 0.624 |
| 107 | 341 | 80.7 | 50.7 | 358 | 0.975 | 0.97 | 0.84 | 0.1661 | 6.02 | 0.584 |
| 102 | 298 | 80.0 | 50.0 | 358 | 0.850 | 0.84 | 0.84 | 0.1657 | 6.04 | 0.583 |
| 97 | 254 | 79.3 | 49.3 | 359 | 0.725 | 0.72 | 0.84 | 0.1668 | 6.00 | 0.586 |
| 92 | 210 | 78.7 | 48.7 | 359 | 0.600 | 0.61 | 0.84 | 0.1703 | 5.87 | 0.599 |
| 87 | 166 | 78.0 | 48.0 | 360 | 0.475 | 0.50 | 0.84 | 0.1782 | 5.61 | 0.626 |
| 82 | 123 | 77.3 | 47.3 | 360 | 0.350 | 0.41 | 0.84 | 0.1951 | 5.13 | 0.686 |
| 77 | 79 | 76.7 | 46.7 | 360 | 0.225 | 0.32 | 0.84 | 0.2361 | 4.24 | 0.830 |
| 72 | 35 | 76 | 46 | 360 | 0.100 | 0.23 | 0.85 | 0.3918 | 2.55 | 1.377 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2542: Weather Data for Saturday

TMY temperature data for climate zone 13

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | 1 | 3 | 3 | | | | | | | | | | | | | | | | | | |
| 32 | 4 | 6 | 10 | 14 | 15 | 19 | 19 | 7 | | | | | | | | | | | | | 2 | 4 | 4 | 4 | |
| 37 | 27 | 32 | 34 | 34 | 37 | 32 | 31 | 26 | 17 | 8 | 1 | | | | | | | 2 | 5 | 7 | 6 | 9 | 17 | 26 | |
| 42 | 41 | 40 | 36 | 41 | 37 | 42 | 43 | 34 | 24 | 19 | 13 | 8 | 3 | 3 | 3 | 3 | 5 | 7 | 10 | 19 | 27 | 31 | 32 | 32 | |
| 47 | 50 | 54 | 64 | 65 | 65 | 55 | 48 | 45 | 38 | 24 | 20 | 15 | 11 | 9 | 9 | 8 | 14 | 19 | 29 | 26 | 33 | 42 | 49 | 50 | |
| 52 | 61 | 61 | 61 | 59 | 56 | 53 | 49 | 48 | 49 | 49 | 41 | 35 | 25 | 24 | 21 | 23 | 30 | 45 | 41 | 59 | 58 | 60 | 56 | 55 | |
| 57 | 43 | 42 | 41 | 44 | 48 | 42 | 38 | 39 | 36 | 39 | 46 | 46 | 42 | 41 | 41 | 39 | 42 | 42 | 49 | 43 | 47 | 37 | 44 | 50 | |
| 62 | 35 | 44 | 52 | 63 | 55 | 46 | 39 | 36 | 37 | 35 | 36 | 37 | 39 | 38 | 43 | 37 | 41 | 36 | 40 | 38 | 36 | 40 | 29 | 33 | |
| 67 | 53 | 52 | 40 | 21 | 33 | 47 | 48 | 39 | 37 | 31 | 26 | 27 | 36 | 39 | 31 | 36 | 33 | 32 | 28 | 25 | 22 | 28 | 39 | 39 | |
| 72 | 33 | 26 | 22 | 23 | 17 | 20 | 27 | 41 | 42 | 37 | 33 | 33 | 26 | 23 | 27 | 25 | 24 | 27 | 25 | 32 | 33 | 37 | 47 | 42 | 60.28571 |
| 77 | 15 | 8 | 5 | 1 | 1 | 6 | 18 | 35 | 39 | 41 | 39 | 36 | 29 | 30 | 27 | 26 | 25 | 24 | 32 | 30 | 43 | 42 | 29 | 25 | 61.57143 |
| 82 | 3 | | | 0 | | | 2 | 13 | 33 | 45 | 44 | 35 | 39 | 36 | 35 | 35 | 30 | 35 | 28 | 38 | 39 | 27 | 18 | 9 | 64 |
| 87 | | | | | | | | 2 | 12 | 31 | 38 | 42 | 39 | 31 | 27 | 29 | 36 | 27 | 42 | 36 | 17 | 8 | 1 | | 56 |
| 92 | | | | | | | | | 1 | 6 | 25 | 36 | 37 | 39 | 42 | 43 | 39 | 37 | 26 | 12 | 2 | | | | 49 |
| 97 | | | | | | | | | | | 3 | 15 | 31 | 36 | 36 | 31 | 27 | 27 | 10 | | | | | | 30.85714 |
| 102 | | | | | | | | | | | | | 8 | 15 | 22 | 27 | 19 | 5 | | | | | | | 13.71429 |
| 107 | | | | | | | | | | | | | | 1 | 1 | 3 | | | | | | | | | 0.714286 |
| 112 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| On Hours | | | | | | | 47 | 91 | 127 | 160 | 182 | 197 | 209 | 211 | 217 | 219 | 200 | 182 | 163 | 148 | | | | | 336.14 |

TMY values are scaled by 1/7 to account for Saturday operation only

Actual temperature by hour from 06/21/97 to 08/10/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 27 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 32 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 37 | . | . | . | . | 1 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 42 | 1 | 2 | 2 | 2 | 1 | 1 | 2 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | |
| 47 | 1 | . | 2 | 2 | 4 | 3 | 4 | 1 | 1 | . | . | . | . | 1 | 1 | . | . | . | 1 | 1 | 1 | 1 | 2 | . | |
| 52 | 7 | 9 | 9 | 10 | 10 | 12 | 9 | 7 | 4 | 3 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 6 | |
| 57 | 7 | 8 | 7 | 8 | 7 | 8 | 6 | 10 | 5 | 3 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 3 | 3 | 5 | 7 | 7 | 8 | 10 | |
| 62 | 12 | 10 | 15 | 18 | 19 | 16 | 14 | 9 | 10 | 9 | 5 | 3 | 4 | 3 | 3 | 3 | 3 | 2 | 6 | 6 | 7 | 12 | 11 | 8 | |
| 67 | 13 | 18 | 15 | 15 | 14 | 18 | 19 | 9 | 9 | 6 | 9 | 8 | 4 | 4 | 2 | 4 | 5 | 7 | 5 | 7 | 6 | 3 | 7 | 9 | |
| 72 | 16 | 14 | 12 | 10 | 11 | 8 | 8 | 17 | 9 | 12 | 7 | 5 | 8 | 5 | 7 | 6 | 6 | 6 | 5 | 6 | 7 | 9 | 14 | 14 | 107 |
| 77 | 8 | 5 | 5 | 3 | 2 | 2 | 6 | 9 | 18 | 8 | 9 | 11 | 7 | 9 | 6 | 5 | 4 | 5 | 5 | 9 | 11 | 11 | 11 | 13 | 111 |
| 82 | 2 | 3 | 2 | 1 | . | . | 1 | 5 | 9 | 19 | 13 | 8 | 7 | 7 | 7 | 7 | 8 | 9 | 11 | 7 | 12 | 16 | 9 | 5 | 118 |
| 87 | 2 | . | . | . | . | . | . | 1 | 3 | 6 | 13 | 16 | 12 | 8 | 10 | 10 | 8 | 7 | 13 | 16 | 12 | 7 | 5 | 3 | 123 |
| 92 | . | . | . | . | . | . | . | . | 1 | 2 | 6 | 9 | 14 | 18 | 17 | 16 | 17 | 18 | 13 | 9 | 4 | . | | . | 140 |
| 97 | . | . | . | . | . | . | . | . | . | 1 | 2 | 4 | 8 | 9 | 7 | 9 | 9 | 9 | 5 | 2 | 1 | 1 | . | . | 65 |
| 102 | . | . | . | . | . | . | . | . | . | . | . | 1 | 2 | 2 | 5 | 4 | 5 | . | 1 | . | . | | . | . | 20 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 2 | 2 | 1 | 1 | . | . | . | . | . | . | 7 |
| 112 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | | . | . | . | . | . | . | 0 |
| On Hours | | | | | | | 15 | 32 | 40 | 48 | 50 | 54 | 58 | 59 | 61 | 59 | 58 | 55 | 53 | 49 | | | | | 691.00 |

Actual temperature by hour from 08/11/98 to 08/10/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 27 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 32 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 37 | . | . | . | . | 1 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 42 | 1 | 1 | 1 | 1 | . | . | 1 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | |
| 47 | . | . | 2 | 2 | 3 | 2 | 3 | . | 1 | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | 1 | 1 | . | |
| 52 | 4 | 4 | 2 | 3 | 3 | 5 | 3 | 3 | 1 | 1 | 1 | . | . | 1 | 1 | 1 | 1 | 1 | . | . | . | . | . | 1 | |
| 57 | 2 | 5 | 5 | 6 | 6 | 5 | 4 | 5 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 4 | 8 | |
| 62 | 9 | 7 | 8 | 9 | 7 | 7 | 7 | 5 | 6 | 5 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 3 | 5 | 9 | 8 | 3 | |
| 67 | 5 | 7 | 7 | 6 | 7 | 7 | 8 | 3 | 5 | 3 | 7 | 5 | 1 | 1 | 1 | 1 | . | 2 | 3 | 4 | 4 | 1 | 1 | 4 | |
| 72 | 6 | 4 | 3 | 2 | 3 | 3 | 1 | 8 | 4 | 7 | 3 | 3 | 5 | 3 | 3 | 3 | 3 | 4 | 4 | 3 | 3 | 3 | 7 | 6 | 54 |
| 77 | 2 | 1 | 2 | 2 | 1 | 1 | 4 | 3 | 8 | 3 | 5 | 7 | 4 | 5 | 3 | 3 | 3 | 3 | 2 | 5 | 4 | 5 | 6 | 4 | 58 |
| 82 | 1 | 2 | 1 | . | . | . | . | 3 | 1 | 8 | 6 | 3 | 4 | 5 | 5 | 5 | 5 | 4 | 6 | 1 | 6 | 7 | 1 | 3 | 56 |
| 87 | 1 | . | . | . | . | . | . | . | 3 | 1 | 4 | 6 | 6 | 3 | 4 | 4 | 3 | 3 | 5 | 9 | 4 | 3 | 3 | 1 | 51 |
| 92 | . | . | . | . | . | . | . | . | . | 2 | 2 | 2 | 5 | 7 | 7 | 7 | 8 | 8 | 4 | 3 | 2 | . | . | . | 55 |
| 97 | . | . | . | . | . | . | . | . | . | . | 1 | 3 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | . | . | . | . | . | 20 |
| 102 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 2 | 2 | 2 | 3 | . | . | . | . | . | . | . | 10 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | . | . | . | . | . | . | . | . | 2 |
| 112 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| On Hours | | | | | | | 5 | 14 | 16 | 21 | 21 | 24 | 27 | 27 | 27 | 27 | 27 | 25 | 24 | 21 | | | | | 306.00 |

Site 2542: Weather Data for Monday-Friday

TMY temperature data for climate zone 13

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | 1 | 3 | 3 | | | | | | | | | | | | | | | | | | |
| 32 | 4 | 6 | 10 | 14 | 15 | 19 | 19 | 7 | | | | | | | | | | | | | 2 | 4 | 4 | 4 | |
| 37 | 27 | 32 | 34 | 34 | 37 | 32 | 31 | 26 | 17 | 8 | 1 | | | | | | | 2 | 5 | 7 | 6 | 9 | 17 | 26 | |
| 42 | 41 | 40 | 36 | 41 | 37 | 42 | 43 | 34 | 24 | 19 | 13 | 8 | 3 | 3 | 3 | 3 | 5 | 7 | 10 | 19 | 27 | 31 | 32 | 32 | |
| 47 | 50 | 54 | 64 | 65 | 65 | 55 | 48 | 45 | 38 | 24 | 20 | 15 | 11 | 9 | 9 | 8 | 14 | 19 | 29 | 26 | 33 | 42 | 49 | 50 | |
| 52 | 61 | 61 | 61 | 59 | 56 | 53 | 49 | 48 | 49 | 49 | 41 | 35 | 25 | 24 | 21 | 23 | 30 | 45 | 41 | 59 | 58 | 60 | 56 | 55 | |
| 57 | 43 | 42 | 41 | 44 | 48 | 42 | 38 | 39 | 36 | 39 | 46 | 46 | 42 | 41 | 41 | 39 | 42 | 42 | 49 | 43 | 47 | 37 | 44 | 50 | |
| 62 | 35 | 44 | 52 | 63 | 55 | 46 | 39 | 36 | 37 | 35 | 36 | 37 | 39 | 38 | 43 | 37 | 41 | 36 | 40 | 38 | 36 | 40 | 29 | 33 | |
| 67 | 53 | 52 | 40 | 21 | 33 | 47 | 48 | 39 | 37 | 31 | 26 | 27 | 36 | 39 | 31 | 36 | 33 | 32 | 28 | 25 | 22 | 28 | 39 | 39 | |
| 72 | 33 | 26 | 22 | 23 | 17 | 20 | 27 | 41 | 42 | 37 | 33 | 33 | 26 | 23 | 27 | 25 | 24 | 27 | 25 | 32 | 33 | 37 | 47 | 42 | 351.4286 |
| 77 | 15 | 8 | 5 | 1 | 1 | 6 | 18 | 35 | 39 | 41 | 39 | 36 | 29 | 30 | 27 | 26 | 25 | 24 | 32 | 30 | 43 | 42 | 29 | 25 | 368.5714 |
| 82 | 3 | | | 0 | | | 2 | 13 | 33 | 45 | 44 | 35 | 39 | 36 | 35 | 35 | 30 | 35 | 28 | 38 | 39 | 27 | 18 | 9 | 367.1429 |
| 87 | | | | | | | | 2 | 12 | 31 | 38 | 42 | 39 | 31 | 27 | 29 | 36 | 27 | 42 | 36 | 17 | 8 | 1 | | 297.8571 |
| 92 | | | | | | | | | 1 | 6 | 25 | 36 | 37 | 39 | 42 | 43 | 39 | 37 | 26 | 12 | 2 | | | | 246.4286 |
| 97 | | | | | | | | | | | 3 | 15 | 31 | 36 | 36 | 31 | 27 | 27 | 10 | | | | | | 154.2857 |
| 102 | | | | | | | | | | | | | 8 | 15 | 22 | 27 | 19 | 5 | | | | | | | 68.57143 |
| 107 | | | | | | | | | | | | | | 1 | 1 | 3 | | | | | | | | | 3.571429 |
| 112 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| On Hours | | | | | | | 47 | 91 | 127 | 160 | 182 | 197 | 209 | 211 | 217 | 219 | 200 | 182 | 163 | 148 | 134 | 114 | | | 1857.86 |

TMY values are scaled by 5/7 to account for Monday - Friday operation only

Actual temperature by hour from 06/21/97 to 08/10/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5.00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 27 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | | |
| 32 | . | . | . | . | . | . | . | . | . | . | . | . | . | | | . | . | . | . | . | . | . | . | | |
| 37 | . | . | . | . | 1 | 1 | . | . | . | | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 42 | 2 | 3 | 4 | 6 | 6 | 6 | 6 | 2 | . | | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | 2 | 1 | |
| 47 | 13 | 14 | 17 | 17 | 21 | 21 | 20 | 10 | 7 | 5 | 1 | 1 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 6 | 7 | 10 | |
| 52 | 23 | 23 | 32 | 42 | 44 | 49 | 34 | 23 | 8 | 7 | 9 | 6 | 5 | 3 | 2 | 3 | 2 | 6 | 6 | 10 | 8 | 8 | 11 | 16 | |
| 57 | 42 | 56 | 53 | 52 | 55 | 49 | 54 | 46 | 29 | 15 | 10 | 8 | 6 | 5 | 6 | 5 | 9 | 6 | 8 | 7 | 15 | 26 | 29 | 40 | |
| 62 | 51 | 50 | 58 | 56 | 60 | 60 | 51 | 46 | 52 | 32 | 20 | 15 | 10 | 12 | 10 | 11 | 11 | 13 | 19 | 26 | 36 | 39 | 54 | 52 | |
| 67 | 49 | 46 | 48 | 57 | 60 | 63 | 60 | 55 | 44 | 51 | 36 | 29 | 30 | 22 | 17 | 16 | 16 | 23 | 29 | 42 | 42 | 45 | 45 | 47 | |
| 72 | 59 | 63 | 63 | 62 | 54 | 52 | 49 | 52 | 49 | 43 | 48 | 41 | 28 | 23 | 28 | 28 | 30 | 32 | 35 | 36 | 40 | 43 | 44 | 52 | 605 |
| 77 | 50 | 47 | 37 | 30 | 26 | 24 | 45 | 50 | 53 | 47 | 42 | 40 | 44 | 47 | 40 | 35 | 38 | 43 | 42 | 40 | 44 | 47 | 59 | 60 | 697 |
| 82 | 33 | 26 | 20 | 13 | 9 | 11 | 15 | 39 | 52 | 60 | 52 | 48 | 38 | 32 | 32 | 36 | 39 | 35 | 39 | 45 | 51 | 60 | 48 | 33 | 673 |
| 87 | 15 | 9 | 5 | 2 | 1 | 1 | 3 | 13 | 31 | 46 | 57 | 56 | 49 | 49 | 41 | 41 | 38 | 43 | 48 | 54 | 54 | 37 | 24 | 23 | 660 |
| 92 | . | . | . | . | . | . | . | 1 | 12 | 24 | 40 | 45 | 58 | 52 | 51 | 51 | 51 | 51 | 57 | 48 | 26 | 22 | 13 | 3 | 589 |
| 97 | . | . | . | . | . | . | . | . | . | 7 | 19 | 35 | 41 | 51 | 55 | 52 | 54 | 52 | 32 | 21 | 16 | 3 | 1 | . | 438 |
| 102 | . | . | . | . | . | . | . | . | . | . | 3 | 12 | 24 | 29 | 37 | 39 | 32 | 24 | 16 | 4 | . | . | . | . | 220 |
| 107 | . | | . | . | . | . | . | . | . | . | . | 1 | 2 | 9 | 14 | 16 | 13 | 6 | 2 | . | . | . | . | . | 63 |
| 112 | . | | . | . | | . | . | . | . | . | . | | . | . | 1 | 1 | 1 | . | . | . | . | . | . | . | 3 |
| On Hours | | | | | | | 112 | 155 | 197 | 227 | 261 | 278 | 284 | 292 | 299 | 299 | 296 | 286 | 271 | 248 | 231 | 212 | | | 3948.00 |

Actual temperature by hour from 08/11/98 to 08/10/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10.00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | . | . | . | . | . | . | . | . | . | . | . | . | | | . | . | . | . | . | . | . | . | . | . | |
| 27 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 32 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 37 | . | . | . | . | 1 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 42 | 2 | 3 | 3 | 3 | 2 | 2 | 4 | 1 | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | 1 | 1 | |
| 47 | 7 | 6 | 6 | 7 | 9 | 11 | 8 | 7 | 5 | 3 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 4 | 5 | 5 | |
| 52 | 7 | 8 | 15 | 20 | 23 | 24 | 15 | 9 | 4 | 4 | 5 | 3 | 2 | . | . | . | . | 1 | 3 | 4 | 3 | 2 | 2 | 8 | |
| 57 | 20 | 29 | 29 | 29 | 31 | 30 | 35 | 22 | 12 | 6 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 2 | 3 | 7 | 11 | 13 | 13 | |
| 62 | 30 | 28 | 27 | 26 | 27 | 24 | 24 | 26 | 27 | 11 | 12 | 7 | 3 | 4 | 3 | 1 | 4 | 6 | 7 | 10 | 12 | 15 | 29 | 32 | |
| 67 | 23 | 23 | 26 | 27 | 27 | 29 | 25 | 25 | 24 | 33 | 11 | 10 | 12 | 10 | 9 | 10 | 8 | 9 | 11 | 17 | 23 | 30 | 28 | 25 | |
| 72 | 27 | 26 | 22 | 21 | 15 | 14 | 17 | 25 | 22 | 22 | 31 | 23 | 11 | 5 | 7 | 7 | 7 | 12 | 21 | 25 | 28 | 21 | 16 | 25 | 284 |
| 77 | 16 | 13 | 12 | 9 | 10 | 10 | 12 | 14 | 22 | 18 | 19 | 21 | 27 | 28 | 23 | 20 | 24 | 30 | 26 | 23 | 19 | 20 | 29 | 21 | 346 |
| 82 | 11 | 10 | 9 | 8 | 6 | 6 | 10 | 14 | 19 | 26 | 26 | 25 | 21 | 19 | 20 | 24 | 25 | 16 | 17 | 17 | 18 | 26 | 12 | 9 | 323 |
| 87 | 9 | 6 | 3 | 2 | 1 | 1 | 2 | 8 | 10 | 17 | 20 | 22 | 23 | 24 | 20 | 20 | 16 | 19 | 17 | 26 | 21 | 9 | 9 | 11 | 274 |
| 92 | . | . | . | . | . | . | . | 1 | 7 | 8 | 14 | 18 | 22 | 22 | 23 | 22 | 23 | 24 | 28 | 13 | 11 | 12 | 8 | 2 | 248 |
| 97 | . | . | . | . | . | . | . | . | . | 4 | 8 | 11 | 13 | 18 | 20 | 22 | 22 | 17 | 9 | 12 | 7 | 1 | . | . | 164 |
| 102 | . | . | . | . | . | . | . | . | . | . | 2 | 7 | 12 | 13 | 13 | 11 | 11 | 12 | 9 | . | . | . | . | . | 90 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | | 1 | 3 | 8 | 9 | 6 | 1 | . | . | . | . | . | . | 28 |
| 112 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| On Hours | | | | | | | 41 | 62 | 80 | 95 | 120 | 127 | 130 | 132 | 134 | 135 | 134 | 131 | 127 | 116 | 104 | 89 | | | 1757.00 |

Site 2342: Weather Data

TMY temperature data for climate zone 13

| Temp | On Hours |
|---|---|
| 22 | |
| 27 | |
| 32 | |
| 37 | |
| 42 | |
| 47 | |
| 52 | |
| 57 | |
| 62 | |
| 67 | |
| 72 | 411.7143 |
| 77 | 430.1429 |
| 82 | 431.1429 |
| 87 | 353.8571 |
| 92 | 295.4286 |
| 97 | 185.1429 |
| 102 | 82.28571 |
| 107 | 4.285714 |
| 112 | 0 |
| On Hours | **2194.00** |

Actual temperature by hour from 06/21/97 to 08/10/99

| Temp | On Hours |
|---|---|
| 22 | |
| 27 | |
| 32 | |
| 37 | |
| 42 | |
| 47 | |
| 52 | |
| 57 | |
| 62 | |
| 67 | |
| 72 | 712 |
| 77 | 808 |
| 82 | 791 |
| 87 | 783 |
| 92 | 729 |
| 97 | 503 |
| 102 | 240 |
| 107 | 70 |
| 112 | 3 |
| On Hours | **4639.00** |

Actual temperature by hour from 08/11/98 to 08/10/99

| Temp | On Hours |
|---|---|
| 22 | |
| 27 | |
| 32 | |
| 37 | |
| 42 | |
| 47 | |
| 52 | |
| 57 | |
| 62 | |
| 67 | |
| 72 | 338 |
| 77 | 404 |
| 82 | 379 |
| 87 | 325 |
| 92 | 303 |
| 97 | 184 |
| 102 | 100 |
| 107 | 30 |
| 112 | 0 |
| On Hours | **2063.00** |

**Chiller & Cooling Tower Replacement (Site 2670)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | High Efficiency Water-Cooled Chillers and Cooling Tower |
| Site Description | Health Care/Hospital |

**Measure Description**

Replace 2 existing 225-ton water-cooled chillers with 300-ton high-efficiency water-cooled chillers and replace cooling tower with oversized cooling tower.

**Summary of Ex Ante Impact Calculations**

Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and chiller characteristics.

**Comments on PG&E Calculations**

The correct climate zone and building characteristics were used in the application calculations. However, the simulation modeled one 400-ton chiller instead of two 225-ton chillers. This error also resulted in an incorrect baseline efficiency of 0.747 kW/ton. The incorrect chiller caused the model to underestimate the energy impacts associated with the chiller and cooling tower retrofit.

**Evaluation Process**

The evaluation process consists of a review of the application form and supporting documentation, conducting an on-site survey and then computing impacts using the on-site data.

The on-site survey was conducted on August 11, 1999 in Fresno (Climate Zone 13). Information on the retrofit equipment and operating conditions was collected through an inspection of the chillers and through an interview with the Building Maintenance Superintendent.

Discussions provided data for development of a relationship between chiller loading and outdoor dry bulb. The two chillers, chiller #1 and chiller #2 are operated in a lead/lag configuration. Once the lag chiller is brought on line, the two chillers split the load with the lead chiller running 10 to 20% higher than the lag chiller. The chillers are alternated between lead and lag approximately once per week. The chillers are available 24 hours per day, 7 days per week. The lead chiller is brought on line at 55 degrees F outside air temperature. The lag chiller is brought on line at 80 degrees F outside air temperature. The contact stated that the chillers have never been fully loaded, and estimated that the chillers reached 70% loading for the lead chiller and 50% loading for the lag chiller at 107 degrees F outside air temperature.

Models are calibrated with actual weather, observed chiller run hours since the installation, chiller loading under extreme outdoor temperature conditions, chilled water temperature, and condenser water temperature. Energy impacts are based on typical weather data. A Title 24 baseline, nominal efficiency, and typical year bin weather data for the applicable climate zone are used in the bin analysis. To compute the impacts, the following assumptions were used:

- A linear loading strategy was used for the analysis of both the baseline and rebated chillers, which assumed initial loading of chiller #1 at 55 degrees F and 100% loading at 80 Degrees F. At this point, chiller #2 comes on line, and both chillers operate until the lead chiller reaches 70% loading and the lag chiller reaches 50% loading at 107 degrees F. Both chillers have not reached 100% loading yet.

- Based on a water-cooled chiller between 150 and 300 tons, a baseline Title 24 efficiency of 0.837 KW/ton was used.

- The new cooling tower provides energy savings of 0.01 kW/ton for each degree decrease in approach temperature.

Chiller efficiencies at various temperatures were calculated from updated default performance coefficients provided in a memo to the California Energy Commission titled "1995 Proposed Changes to the ACM Manual Central Plant Cooling Equipment" by Mark Hydeman. These coefficients were used to develop a chiller efficiency curve for the Rebate case and a Title 24 base case. Both evaluation-based demand and energy impacts were higher than Ex Ante estimates. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 58 | 180,468.06 | 0 |
| **Adjusted Engineering** | 125.04 | 337,345.75 | 0 |
| **Engineering Realization Rate** | 2.16 | 1.87 | N/A |

Site 2670: Results With Cooling Tower

| Impacts | Energy | Demand |
|---|---|---|
| MDSS | 180,468 | 58 |
| QC | 337,346 | 125 |
| Realization Rate | 1.87 | 2.16 |

| Title 24 Baseline Chiller #1 | |
|---|---|
| Nom. Eff | 0.837 |
| Nom. Tons | 300 |
| nom kw | 251.143 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 112 | 0.00 | 222 | 0.772 | 0.00 | 171.30 |
| 107 | 5.00 | 210 | 0.770 | 808.67 | 161.73 |
| 102 | 96.00 | 198 | 0.771 | 14,655.37 | 152.66 |
| 97 | 216.00 | 186 | 0.775 | 31,118.23 | 144.07 |
| 92 | 345.00 | 174 | 0.781 | 46,899.39 | 135.94 |
| 87 | 418.00 | 162 | 0.792 | 53,617.68 | 128.27 |
| 82 | 544.00 | 150 | 0.807 | 65,851.15 | 121.05 |
| 77 | 606.00 | 250 | 0.722 | 109,339.26 | 180.43 |
| 72 | 722.00 | 200 | 0.731 | 105,622.89 | 146.29 |
| 67 | 842.00 | 150 | 0.787 | 99,425.84 | 118.08 |
| 62 | 965.00 | 100 | 0.957 | 92,307.68 | 95.66 |
| 57 | 1,021.00 | 50 | 1.577 | 80,526.54 | 78.87 |
| Totals | 5,780.00 | | | 700,172.69 | 180.43 |

| Post-Retrofit Chiller #1 | |
|---|---|
| Nom. Eff | 0.57 |
| Nom. Tons | 300 |
| nom kw | 171 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 112 | 0.00 | 222 | 0.465 | 0.00 | 103.32 | 0.00 | 0.00 |
| 107 | 5.00 | 210 | 0.464 | 487.62 | 97.52 | 2,870.00 | 279,891.43 |
| 102 | 96.00 | 198 | 0.465 | 8,838.18 | 92.06 | 0.00 | 0.00 |
| 97 | 216.00 | 186 | 0.467 | 18,777.45 | 86.93 | 12.00 | 1,043.19 |
| 92 | 345.00 | 174 | 0.472 | 28,331.40 | 82.12 | 54.00 | 4,434.48 |
| 87 | 418.00 | 162 | 0.479 | 32,444.64 | 77.62 | 125.00 | 9,702.34 |
| 82 | 544.00 | 150 | 0.489 | 39,941.21 | 73.42 | 254.00 | 18,649.02 |
| 77 | 606.00 | 250 | 0.431 | 65,357.72 | 107.85 | 4,139.00 | 446,395.39 |
| 72 | 722.00 | 200 | 0.438 | 63,253.29 | 87.61 | 339.00 | 29,699.26 |
| 67 | 842.00 | 150 | 0.476 | 60,119.80 | 71.40 | 385.00 | 27,489.46 |
| 62 | 965.00 | 100 | 0.591 | 57,061.13 | 59.13 | 410.00 | 24,243.59 |
| 57 | 1,021.00 | 50 | 1.014 | 51,766.50 | 50.70 | 411.00 | 20,838.43 |
| Totals | 5,780.00 | | | 426,378.95 | 107.85 | 8,999.00 | 862,386.59 |

| Title 24 Baseline Chiller #2 | |
|---|---|
| Nom. Eff | 0.837 |
| Nom. Tons | 300 |
| nom kw | 251.143 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 112 | 0.00 | 162 | 0.827 | 0.00 | 133.94 |
| 107 | 5.00 | 150 | 0.842 | 631.78 | 126.36 |
| 102 | 96.00 | 138 | 0.864 | 11,445.83 | 119.23 |
| 97 | 216.00 | 126 | 0.893 | 24,310.07 | 112.55 |
| 92 | 345.00 | 114 | 0.932 | 36,674.16 | 106.30 |
| 87 | 418.00 | 102 | 0.985 | 42,001.75 | 100.48 |
| 82 | 544.00 | 90 | 1.056 | 51,722.68 | 95.08 |
| Totals | 1,624.00 | | | 166,786.27 | 133.94 |

| Post-Retrofit Chiller #2 | |
|---|---|
| Nom. Eff | 0.57 |
| Nom. Tons | 300 |
| nom kw | 171 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 112 | 0.00 | 162 | 0.503 | 0.00 | 81.48 | 0.00 | 0.00 |
| 107 | 5.00 | 150 | 0.514 | 385.17 | 77.03 | 35.00 | 2,696.18 |
| 102 | 96.00 | 138 | 0.528 | 6,998.44 | 72.90 | 107.00 | 7,800.35 |
| 97 | 216.00 | 126 | 0.548 | 14,919.46 | 69.07 | 224.00 | 15,472.03 |
| 92 | 345.00 | 114 | 0.575 | 22,611.17 | 65.54 | 370.00 | 24,249.67 |
| 87 | 418.00 | 102 | 0.611 | 26,040.30 | 62.30 | 434.00 | 27,037.06 |
| 82 | 544.00 | 90 | 0.659 | 32,279.72 | 59.34 | 553.00 | 32,813.76 |
| Totals | 1,624.00 | | | 103,234.26 | 81.48 | 1,723.00 | 110,069.04 |

Note: The effect of the new cooling tower is a 0.01 kW/ton decrease per degree decrease in approach temperature for the post-retrofit case only.

Site 2670: Results Without Cooling Tower

| Impacts | Energy | Demand |
|---|---|---|
| MDSS | 180,468 | 58 |
| QC | 276,658 | 100 |
| Realization Rate | 1.53 | 1.73 |

| Title 24 Baseline Chiller #1 | |
|---|---|
| Nom. Eff | 0.837 |
| Nom. Tons | 300 |
| nom kw | 251.143 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 112 | 0.00 | 222 | 0.77 | 0.00 | 171.30 |
| 107 | 5.00 | 210 | 0.77 | 808.67 | 161.73 |
| 102 | 96.00 | 198 | 0.77 | 14,655.37 | 152.66 |
| 97 | 216.00 | 186 | 0.77 | 31,118.23 | 144.07 |
| 92 | 345.00 | 174 | 0.78 | 46,899.39 | 135.94 |
| 87 | 418.00 | 162 | 0.79 | 53,617.68 | 128.27 |
| 82 | 544.00 | 150 | 0.81 | 65,851.15 | 121.05 |
| 77 | 606.00 | 250 | 0.72 | 109,339.26 | 180.43 |
| 72 | 722.00 | 200 | 0.73 | 105,622.89 | 146.29 |
| 67 | 842.00 | 150 | 0.79 | 99,425.84 | 118.08 |
| 62 | 965.00 | 100 | 0.96 | 92,307.68 | 95.66 |
| 57 | 1,021.00 | 50 | 1.58 | 80,526.54 | 78.87 |
| Totals | 5,780.00 | | | 700,172.69 | 180.43 |

| Post-Retrofit Chiller #1 | |
|---|---|
| Nom. Eff | 0.57 |
| Nom. Tons | 300 |
| nom kw | 171 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 112 | 0.00 | 222 | 0.53 | 0.00 | 116.64 | 0.00 | 0.00 |
| 107 | 5.00 | 210 | 0.52 | 550.62 | 110.12 | 2,870.00 | 316,053.43 |
| 102 | 96.00 | 198 | 0.52 | 9,978.66 | 103.94 | 0.00 | 0.00 |
| 97 | 216.00 | 186 | 0.53 | 21,188.01 | 98.09 | 12.00 | 1,177.11 |
| 92 | 345.00 | 174 | 0.53 | 31,933.20 | 92.56 | 54.00 | 4,998.24 |
| 87 | 418.00 | 162 | 0.54 | 36,507.60 | 87.34 | 125.00 | 10,917.34 |
| 82 | 544.00 | 150 | 0.55 | 44,837.21 | 82.42 | 254.00 | 20,935.02 |
| 77 | 606.00 | 250 | 0.49 | 74,447.72 | 122.85 | 4,139.00 | 508,480.39 |
| 72 | 722.00 | 200 | 0.50 | 71,917.29 | 99.61 | 339.00 | 33,767.26 |
| 67 | 842.00 | 150 | 0.54 | 67,697.80 | 80.40 | 385.00 | 30,954.46 |
| 62 | 965.00 | 100 | 0.65 | 62,851.13 | 65.13 | 410.00 | 26,703.59 |
| 57 | 1,021.00 | 50 | 1.07 | 54,829.50 | 53.70 | 411.00 | 22,071.43 |
| Totals | 5,780.00 | | | 476,738.75 | 122.85 | 8,999.00 | 976,058.27 |

| Title 24 Baseline Chiller #2 | |
|---|---|
| Nom. Eff | 0.837 |
| Nom. Tons | 300 |
| nom kw | 251.143 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 112 | 0.00 | 162 | 0.83 | 0.00 | 133.94 |
| 107 | 5.00 | 150 | 0.84 | 631.78 | 126.36 |
| 102 | 96.00 | 138 | 0.86 | 11,445.83 | 119.23 |
| 97 | 216.00 | 126 | 0.89 | 24,310.07 | 112.55 |
| 92 | 345.00 | 114 | 0.93 | 36,674.16 | 106.30 |
| 87 | 418.00 | 102 | 0.99 | 42,001.75 | 100.48 |
| 82 | 544.00 | 90 | 1.06 | 51,722.68 | 95.08 |
| Totals | 1,624.00 | | | 166,786.27 | 133.94 |

| Post-Retrofit Chiller #2 | |
|---|---|
| Nom. Eff | 0.57 |
| Nom. Tons | 300 |
| nom kw | 171 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 112 | 0.00 | 162 | 0.56 | 0.00 | 91.20 | 0.00 | 0.00 |
| 107 | 5.00 | 150 | 0.57 | 430.17 | 86.03 | 35.00 | 3,011.18 |
| 102 | 96.00 | 138 | 0.59 | 7,793.32 | 81.18 | 107.00 | 8,686.31 |
| 97 | 216.00 | 126 | 0.61 | 16,552.42 | 76.63 | 224.00 | 17,165.47 |
| 92 | 345.00 | 114 | 0.63 | 24,970.97 | 72.38 | 370.00 | 26,780.47 |
| 87 | 418.00 | 102 | 0.67 | 28,598.46 | 68.42 | 434.00 | 29,693.14 |
| 82 | 544.00 | 90 | 0.72 | 35,217.32 | 64.74 | 553.00 | 35,799.96 |
| Totals | 1,624.00 | | | 113,562.66 | 91.20 | 1,723.00 | 121,136.52 |

Site 2670: Inputs to Model

| Parameter | Value Reported | Units of Parameter | Notes |
|---|---|---|---|
| City | Fresno | | |
| Climate Zone | 13 | | |
| Pre-Retrofit Nominal Chiller Capacity | 225 | Tons | Application |
| Pre-Retrofit Nominal Chiller Efficiency | 1.044 | kW/ton | Application |
| Number of Pre-Retrofit Chillers | 2 | | |
| Post-Retrofit Nominal Chiller Capacity | 300 | Tons | Application |
| Post-Retrofit Nominal Chiller Efficiency | 0.57 | kW/ton | From Chiller Rating Sheet |
| Number of Post-Retrofit Chillers | 2 | | |
| Baseline Chiller Efficiency | 0.837 | kW/ton | Title 24 Nominal Efficiency for Chiller >= 150 Tons and < 300 Tons |
| Pre-Retrofit Cooling Tower Approach Temperature | 10.0 | F | Application |
| Post-Retrofit Cooling Tower Approach Temperature | 4.0 | F | Application |
| | | | |
| Chiller AM Lockout | 4:00 | AM | Contact provided schedule; Chiller is on Manual Operation |
| Chiller PM Lockout | 9:00 | PM | Contact provided schedule; Chiller is on Manual Operation |
| Chiller #1 Startup OSA Temperature | 55 | F | Contact provided estimate |
| Chiller #1 Max Load OSA Temperature | 110 | F | Contact provided estimate |
| Chiller #2 Startup OSA Temperature | 72 | F | Contact provided estimate |
| Chiller #2 Max Load OSA Temperature | 115 | F | Contact provided estimate |
| Chilled Water Supply Temperature Setpoint | 44 | F | Contact provided setpoints; Chiller is on Manual Operation |
| Condenser Water Temperature Setpoint | 77 | F | Contact provided setpoints; Chiller is on Manual Operation |
| Date of Chiller #1 Installation | 4/1/99 | | Contact provided estimate |
| Date of Chiller #2 Installation | 1/20/99 | | Contact provided estimate |
| Date at Run Hour Reading | 8/11/99 | | Chiller Log |
| Number of Days Chiller #1 Operated | 122 | days | = ((Read Date - Install Date) * 5/7) - 10 Holidays |
| Number of Days Chiller #2 Operated | 193 | days | = ((Read Date - Install Date) * 5/7) - 10 Holidays |
| Run Hours for Chiller #1 | 1488 | hours | Documented from Chiller Log |
| Run Hours for Chiller #2 | 1258 | hours | Documented from Chiller Log |
| Average Hours per Year of Chiller #1 Operation | 4451.80 | Hours/Year | = (Run Hours for New Chiller / Number of Days Chiller Operated) * 365 Days/Year * 5/7 |
| Average Hours per Year of Chiller #2 Operation | 2379.12 | Hours/Year | = (Run Hours for New Chiller / Number of Days Chiller Operated) * 365 Days/Year * 5/7 |
| | | | |
| Predicted Run Hours Since Install Using Actual Weather & Setpoints | 2870.00 | hours | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |
| Predicted Hours per Year Using Actual Weather Data & Setpoints | 1723.00 | Hours/Year | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |

Site 2670: Post-Retrofit Chiller #1

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

| | |
|---|---|
| Nom. Eff | 0.57 |
| Nom. Tons | 300 |
| nom kw | 171 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 222 | 79.5 | 44 | 309 | 0.740 | 0.76 | 0.90 | 0.1494 | 6.69 | 0.525 |
| 107 | 210 | 79 | 44 | 310 | 0.700 | 0.72 | 0.89 | 0.1491 | 6.70 | 0.524 |
| 102 | 198 | 78.5 | 44 | 310 | 0.660 | 0.69 | 0.89 | 0.1493 | 6.70 | 0.525 |
| 97 | 186 | 78 | 44 | 311 | 0.620 | 0.65 | 0.88 | 0.1500 | 6.67 | 0.527 |
| 92 | 174 | 77.5 | 44 | 312 | 0.580 | 0.62 | 0.87 | 0.1513 | 6.61 | 0.532 |
| 87 | 162 | 77 | 44 | 313 | 0.540 | 0.59 | 0.86 | 0.1533 | 6.52 | 0.539 |
| 82 | 150 | 76.5 | 44 | 313 | 0.500 | 0.56 | 0.86 | 0.1563 | 6.40 | 0.549 |
| 77 | 250 | 76 | 44 | 314 | 0.833 | 0.85 | 0.85 | 0.1398 | 7.15 | 0.491 |
| 72 | 200 | 75.5 | 44 | 315 | 0.667 | 0.69 | 0.84 | 0.1417 | 7.06 | 0.498 |
| 67 | 150 | 75 | 44 | 316 | 0.500 | 0.56 | 0.83 | 0.1524 | 6.56 | 0.536 |
| 62 | 100 | 74.5 | 44 | 317 | 0.333 | 0.46 | 0.83 | 0.1852 | 5.40 | 0.651 |
| 57 | 50 | 74 | 44 | 317 | 0.167 | 0.38 | 0.82 | 0.3055 | 3.27 | 1.074 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |
| EIRFPLR | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2670: Post-Retrofit Chiller #2

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

| | |
|---|---|
| Nom. Eff | 0.57 |
| Nom. Tons | 300 |
| nom kw | 171 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 162 | 79.5 | 44 | 309 | 0.540 | 0.59 | 0.90 | 0.1601 | 6.25 | 0.563 |
| 107 | 150 | 79 | 44 | 310 | 0.500 | 0.56 | 0.89 | 0.1631 | 6.13 | 0.574 |
| 102 | 138 | 78.5 | 44 | 310 | 0.460 | 0.54 | 0.89 | 0.1673 | 5.98 | 0.588 |
| 97 | 126 | 78 | 44 | 311 | 0.420 | 0.51 | 0.88 | 0.1730 | 5.78 | 0.608 |
| 92 | 114 | 77.5 | 44 | 312 | 0.380 | 0.49 | 0.87 | 0.1806 | 5.54 | 0.635 |
| 87 | 102 | 77 | 44 | 313 | 0.340 | 0.46 | 0.86 | 0.1908 | 5.24 | 0.671 |
| 82 | 90 | 76.5 | 44 | 313 | 0.300 | 0.44 | 0.86 | 0.2046 | 4.89 | 0.719 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |
| EIRFPLR | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2670: Baseline Chiller #1

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

| | |
|---|---|
| Nom. Eff | 0.837 |
| Nom. Tons | 300.000 |
| nom kw | 251.142857 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 222 | 79.5 | 44 | 309 | 0.740 | 0.76 | 0.90 | 0.2195 | 4.56 | 0.772 |
| 107 | 210 | 79 | 44 | 310 | 0.700 | 0.72 | 0.89 | 0.2190 | 4.57 | 0.770 |
| 102 | 198 | 78.5 | 44 | 310 | 0.660 | 0.69 | 0.89 | 0.2193 | 4.56 | 0.771 |
| 97 | 186 | 78 | 44 | 311 | 0.620 | 0.65 | 0.88 | 0.2203 | 4.54 | 0.775 |
| 92 | 174 | 77.5 | 44 | 312 | 0.580 | 0.62 | 0.87 | 0.2222 | 4.50 | 0.781 |
| 87 | 162 | 77 | 44 | 313 | 0.540 | 0.59 | 0.86 | 0.2252 | 4.44 | 0.792 |
| 82 | 150 | 76.5 | 44 | 313 | 0.500 | 0.56 | 0.86 | 0.2295 | 4.36 | 0.807 |
| 77 | 250 | 76 | 44 | 314 | 0.833 | 0.85 | 0.85 | 0.2053 | 4.87 | 0.722 |
| 72 | 200 | 75.5 | 44 | 315 | 0.667 | 0.69 | 0.84 | 0.2080 | 4.81 | 0.731 |
| 67 | 150 | 75 | 44 | 316 | 0.500 | 0.56 | 0.83 | 0.2239 | 4.47 | 0.787 |
| 62 | 100 | 74.5 | 44 | 317 | 0.333 | 0.46 | 0.83 | 0.2721 | 3.68 | 0.957 |
| 57 | 50 | 74 | 44 | 317 | 0.167 | 0.38 | 0.82 | 0.4486 | 2.23 | 1.577 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |
| EIRFPLR | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2670: Baseline Chiller #2

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

| | |
|---|---|
| Nom. Eff | 0.837 |
| Nom. Tons | 300 |
| nom kw | 251.142857 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 162 | 79.5 | 44 | 309 | 0.540 | 0.59 | 0.90 | 0.2352 | 4.25 | 0.827 |
| 107 | 150 | 79 | 44 | 310 | 0.500 | 0.56 | 0.89 | 0.2396 | 4.17 | 0.842 |
| 102 | 138 | 78.5 | 44 | 310 | 0.460 | 0.54 | 0.89 | 0.2457 | 4.07 | 0.864 |
| 97 | 126 | 78 | 44 | 311 | 0.420 | 0.51 | 0.88 | 0.2540 | 3.94 | 0.893 |
| 92 | 114 | 77.5 | 44 | 312 | 0.380 | 0.49 | 0.87 | 0.2652 | 3.77 | 0.932 |
| 87 | 102 | 77 | 44 | 313 | 0.340 | 0.46 | 0.86 | 0.2802 | 3.57 | 0.985 |
| 82 | 90 | 76.5 | 44 | 313 | 0.300 | 0.44 | 0.86 | 0.3005 | 3.33 | 1.056 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |
| EIRFPLR | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2670: Pre-Retrofit Chiller #1

| | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Centrifugal Chiller (Water-Source) | | | | | | |
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

| | |
|---|---|
| Nom. Eff | 1.04444444 |
| Nom. Tons | 225 |
| nom kw | 235 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 222 | 79.5 | 44 | 232 | 0.987 | 1.01 | 0.90 | 0.2744 | 3.64 | 0.965 |
| 107 | 210 | 79 | 44 | 232 | 0.933 | 0.95 | 0.89 | 0.2705 | 3.70 | 0.951 |
| 102 | 198 | 78.5 | 44 | 233 | 0.880 | 0.89 | 0.89 | 0.2674 | 3.74 | 0.940 |
| 97 | 186 | 78 | 44 | 233 | 0.827 | 0.84 | 0.88 | 0.2650 | 3.77 | 0.932 |
| 92 | 174 | 77.5 | 44 | 234 | 0.773 | 0.79 | 0.87 | 0.2635 | 3.80 | 0.926 |
| 87 | 162 | 77 | 44 | 235 | 0.720 | 0.74 | 0.86 | 0.2630 | 3.80 | 0.925 |
| 82 | 150 | 76.5 | 44 | 235 | 0.667 | 0.69 | 0.86 | 0.2639 | 3.79 | 0.928 |
| 77 | 250 | 76 | 44 | 236 | 1.111 | 1.16 | 0.85 | 0.2634 | 3.80 | 0.926 |
| 72 | 200 | 75.5 | 44 | 236 | 0.889 | 0.90 | 0.84 | 0.2542 | 3.93 | 0.894 |
| 67 | 150 | 75 | 44 | 237 | 0.667 | 0.69 | 0.83 | 0.2574 | 3.88 | 0.905 |
| 62 | 100 | 74.5 | 44 | 237 | 0.444 | 0.53 | 0.83 | 0.2911 | 3.44 | 1.023 |
| 57 | 50 | 74 | 44 | 238 | 0.222 | 0.41 | 0.82 | 0.4451 | 2.25 | 1.565 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |
| EIRFPLR | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2670: Pre-Retrofit Chiller #2

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

| | |
|---|---|
| Nom. Eff | 1.044 |
| Nom. Tons | 225 |
| nom kw | 235 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 112 | 162 | 79.5 | 44 | 232 | 0.720 | 0.74 | 0.90 | 0.2747 | 3.64 | 0.966 |
| 107 | 150 | 79 | 44 | 232 | 0.667 | 0.69 | 0.89 | 0.2755 | 3.63 | 0.969 |
| 102 | 138 | 78.5 | 44 | 233 | 0.613 | 0.65 | 0.89 | 0.2779 | 3.60 | 0.977 |
| 97 | 126 | 78 | 44 | 233 | 0.560 | 0.61 | 0.88 | 0.2825 | 3.54 | 0.993 |
| 92 | 114 | 77.5 | 44 | 234 | 0.507 | 0.57 | 0.87 | 0.2898 | 3.45 | 1.019 |
| 87 | 102 | 77 | 44 | 235 | 0.453 | 0.53 | 0.86 | 0.3007 | 3.33 | 1.057 |
| 82 | 90 | 76.5 | 44 | 235 | 0.400 | 0.50 | 0.86 | 0.3166 | 3.16 | 1.113 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |
| EIRFPLR | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2670: Weather Data

TMY temperature data for climate zone 13

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | 1 | 3 | 3 | | | | | | | | | | | | | | | | | | |
| 32 | 4 | 6 | 10 | 14 | 15 | 19 | 19 | 7 | | | | | | | | | | | | | 2 | 4 | 4 | 4 | |
| 37 | 27 | 32 | 34 | 34 | 37 | 32 | 31 | 26 | 17 | 8 | 1 | | | | | | | 2 | 5 | 7 | 6 | 9 | 17 | 26 | |
| 42 | 41 | 40 | 36 | 41 | 37 | 42 | 43 | 34 | 24 | 19 | 13 | 8 | 3 | 3 | 3 | 3 | 5 | 7 | 10 | 19 | 27 | 31 | 32 | 33 | |
| 47 | 50 | 54 | 64 | 65 | 65 | 55 | 48 | 45 | 38 | 24 | 20 | 15 | 11 | 9 | 9 | 8 | 14 | 19 | 29 | 26 | 33 | 47 | 49 | 50 | |
| 52 | 61 | 61 | 61 | 59 | 56 | 53 | 49 | 48 | 49 | 49 | 41 | 35 | 25 | 24 | 21 | 23 | 30 | 45 | 41 | 59 | 58 | 60 | 56 | 55 | |
| 57 | 43 | 42 | 41 | 44 | 48 | 42 | 38 | 39 | 36 | 39 | 46 | 46 | 42 | 41 | 41 | 39 | 42 | 42 | 49 | 43 | 47 | 37 | 44 | 50 | 1073 |
| 62 | 35 | 44 | 52 | 63 | 55 | 46 | 39 | 36 | 37 | 35 | 36 | 37 | 39 | 38 | 43 | 37 | 41 | 36 | 40 | 38 | 36 | 40 | 29 | 33 | 965 |
| 67 | 53 | 52 | 40 | 21 | 33 | 47 | 48 | 39 | 37 | 31 | 26 | 27 | 36 | 39 | 31 | 36 | 33 | 32 | 28 | 25 | 22 | 28 | 39 | 39 | 842 |
| 72 | 33 | 26 | 22 | 23 | 17 | 20 | 27 | 41 | 42 | 37 | 33 | 33 | 26 | 23 | 27 | 25 | 24 | 27 | 25 | 32 | 33 | 37 | 47 | 42 | 722 |
| 77 | 15 | 8 | 5 | 1 | 1 | 6 | 18 | 35 | 39 | 41 | 39 | 36 | 29 | 30 | 27 | 26 | 25 | 24 | 32 | 30 | 43 | 42 | 29 | 25 | 606 |
| 82 | 3 | | | 0 | | | 2 | 13 | 33 | 45 | 44 | 35 | 39 | 36 | 15 | 35 | 30 | 35 | 28 | 38 | 39 | 27 | 18 | 9 | 544 |
| 87 | | | | | | | | 2 | 12 | 31 | 28 | 42 | 39 | 31 | 27 | 29 | 36 | 27 | 42 | 36 | 17 | 8 | 1 | | 418 |
| 92 | | | | | | | | | 1 | 6 | 25 | 36 | 37 | 39 | 42 | 43 | 39 | 37 | 26 | 12 | 2 | | | | 345 |
| 97 | | | | | | | | | | | 3 | 15 | 31 | 36 | 36 | 31 | 27 | 27 | 10 | | | | | | 216 |
| 102 | | | | | | | | | | | | | 8 | 15 | 22 | 27 | 19 | 6 | | | | | | | 96 |
| 107 | | | | | | | | | | | | | | 1 | 1 | 3 | | | | | | | | | 5 |
| 112 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| On Hours | | | | | | | 2 | 13 | 46 | 82 | 110 | 128 | 154 | 158 | 163 | 168 | 50.33 | | | | | | | | 1624.00 |

Actual temperature data for climate zone 13 for 4/1/99 to 7/23/99; Chiller #1

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 32 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 37 | | | | | 3 | 3 | 1 | | | | | | | | | | | | | | | | | | |
| 42 | 4 | 5 | 5 | 5 | 2 | 2 | 5 | 3 | | | | | | | | | | | | 1 | 1 | 1 | 1 | 2 | |
| 47 | 7 | 6 | 7 | 8 | 11 | 11 | 7 | 7 | 7 | 3 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 2 | 3 | 6 | 7 | 6 | |
| 52 | 6 | 7 | 11 | 17 | 20 | 22 | 10 | 5 | 6 | 7 | 8 | 4 | 3 | 2 | 2 | 2 | 2 | 3 | 4 | 5 | 4 | 3 | 3 | 8 | |
| 57 | 18 | 23 | 24 | 22 | 28 | 17 | 22 | 16 | 9 | 6 | 4 | 7 | 7 | 6 | 5 | 4 | 4 | 4 | 6 | 5 | 9 | 8 | 6 | 10 | 262 |
| 62 | 22 | 20 | 21 | 23 | 27 | 27 | 24 | 16 | 18 | 18 | 18 | 7 | 4 | 5 | 5 | 4 | 6 | 5 | 5 | 6 | 8 | 12 | 24 | 22 | 331 |
| 67 | 21 | 31 | 32 | 33 | 31 | 32 | 32 | 26 | 16 | 18 | 18 | 7 | 7 | 6 | 5 | 6 | 5 | 7 | 7 | 12 | 12 | 17 | 17 | 21 | 411 |
| 72 | 34 | 24 | 19 | 14 | 12 | 10 | 16 | 32 | 23 | 23 | 17 | 18 | 11 | 5 | 7 | 7 | 6 | 10 | 13 | 14 | 21 | 20 | 23 | 29 | 410 |
| 77 | 10 | 8 | 9 | 8 | 4 | 6 | 11 | 13 | 29 | 19 | 22 | 15 | 17 | 20 | 15 | 14 | 15 | 16 | 15 | 23 | 20 | 25 | 30 | 21 | 385 |
| 82 | 7 | 6 | 3 | 1 | 2 | 2 | 3 | 11 | 15 | 28 | 27 | 28 | 21 | 16 | 14 | 16 | 20 | 20 | 26 | 18 | 23 | 25 | 8 | 7 | 339 |
| 87 | 4 | 3 | 2 | 2 | 1 | 1 | 2 | 3 | 7 | 12 | 18 | 27 | 22 | 21 | 20 | 20 | 16 | 17 | 19 | 29 | 18 | 9 | 8 | 6 | 287 |
| 92 | | | | | | | | 1 | 3 | 5 | 10 | 16 | 25 | 27 | 27 | 26 | 28 | 29 | 25 | 13 | 8 | 6 | 4 | 1 | 254 |
| 97 | | | | | | | | | | 2 | 5 | 7 | 8 | 15 | 19 | 20 | 18 | 14 | 7 | 5 | 4 | 1 | | | 125 |
| 102 | | | | | | | | | | | 1 | 4 | 6 | 6 | 9 | 8 | 9 | 6 | 5 | | | | | | 54 |
| 107 | | | | | | | | | | | | | 1 | 2 | 3 | 4 | 2 | | | | | | | | 12 |
| 112 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| On Hours | 116 | 115 | 110 | 103 | 97 | 95 | 110 | 118 | 120 | 123 | 124 | 128 | 129 | 129 | 129 | 129 | 129 | 128 | 126 | 125 | 125 | 123 | 122 | 117 | 2870.00 |

Actual temperature data for climate zone 13 for 1/20/99 to 7/23/99, Chiller #2

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 32 | | | 1 | 1 | 1 | 2 | 2 | 1 | | | | | | | | | | | | | | | | | |
| 37 | 3 | 5 | 4 | 6 | 12 | 14 | 13 | 12 | 5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | |
| 42 | 18 | 20 | 23 | 24 | 24 | 26 | 28 | 15 | 13 | 9 | 3 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 4 | 3 | 5 | 10 | 13 | |
| 47 | 30 | 36 | 39 | 37 | 39 | 33 | 30 | 38 | 27 | 16 | 8 | 7 | 5 | 4 | 4 | 6 | 6 | 5 | 9 | 12 | 14 | 22 | 22 | 31 | |
| 52 | 32 | 33 | 22 | 29 | 27 | 31 | 17 | 15 | 27 | 32 | 30 | 19 | 12 | 7 | 8 | 5 | 8 | 14 | 24 | 25 | 32 | 31 | 35 | 34 | |
| 57 | 33 | 28 | 29 | 26 | 24 | 20 | 26 | 21 | 21 | 25 | 27 | 32 | 35 | 30 | 22 | 28 | 27 | 31 | 25 | 26 | 29 | 27 | 21 | 18 | |
| 62 | 22 | 20 | 21 | 23 | 27 | 27 | 24 | 18 | 18 | 14 | 24 | 21 | 18 | 22 | 28 | 21 | 21 | 17 | 18 | 20 | 15 | 14 | 24 | 22 | |
| 67 | 21 | 31 | 32 | 33 | 31 | 32 | 32 | 26 | 16 | 18 | 11 | 16 | 20 | 22 | 16 | 18 | 19 | 20 | 15 | 14 | 13 | 17 | 17 | 21 | |
| 72 | 34 | 24 | 19 | 14 | 12 | 10 | 16 | 32 | 23 | 23 | 17 | 18 | 12 | 9 | 16 | 16 | 13 | 12 | 13 | 14 | 23 | 20 | 23 | 29 | |
| 77 | 10 | 8 | 9 | 8 | 4 | 6 | 11 | 13 | 29 | 19 | 22 | 15 | 17 | 20 | 15 | 14 | 15 | 16 | 15 | 23 | 20 | 25 | 30 | 21 | |
| 82 | 7 | 6 | 3 | 1 | 2 | 2 | 3 | 11 | 15 | 28 | 27 | 28 | 21 | 16 | 14 | 16 | 20 | 20 | 26 | 18 | 23 | 25 | 8 | 7 | 339 |
| 87 | 4 | 3 | 2 | 2 | 1 | 1 | 2 | 3 | 7 | 12 | 18 | 27 | 22 | 21 | 20 | 20 | 16 | 17 | 19 | 29 | 18 | 9 | 8 | 6 | 287 |
| 92 | | | | | | | | 1 | 3 | 5 | 10 | 16 | 25 | 27 | 27 | 26 | 28 | 29 | 25 | 13 | 8 | 6 | 4 | 1 | 254 |
| 97 | | | | | | | | | | 2 | 5 | 7 | 8 | 15 | 19 | 20 | 18 | 14 | 7 | 5 | 4 | 1 | | | 125 |
| 102 | | | | | | | | | | | 1 | 4 | 6 | 6 | 9 | 8 | 9 | 6 | 5 | | | | | | 54 |
| 107 | | | | | | | | | | | | | 1 | 2 | 3 | 4 | 2 | | | | | | | | 12 |
| 112 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| On Hours | 11 | 9 | 5 | 3 | 3 | 3 | 5 | 15 | 25 | 47 | 61 | 74 | 83 | 87 | 92 | 94 | 93 | 86 | 82 | 65 | 53 | 41 | 20 | 14 | 1071.00 |

Actual temperature data for climate zone 13 for 8/12/98 to 8/11/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | | | 1 | 1 | 1 | 2 | 1 | | | | | | | | | | | | | | | | | |
| 27 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 1 | 1 | | | | | | | | | | 1 | 1 | 2 | 3 | |
| 32 | 9 | 9 | 15 | 16 | 15 | 19 | 18 | 16 | 12 | 6 | 2 | 3 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 4 | 2 | 5 | 4 | 5 | |
| 37 | 15 | 21 | 17 | 20 | 27 | 30 | 31 | 28 | 21 | 16 | 13 | 9 | 6 | 3 | 3 | 3 | 5 | 7 | 9 | 11 | 14 | 18 | 19 | 17 | |
| 42 | 33 | 37 | 39 | 37 | 40 | 40 | 44 | 29 | 24 | 18 | 11 | 10 | 12 | 11 | 7 | 6 | 9 | 9 | 12 | 13 | 18 | 16 | 23 | 25 | |
| 47 | 49 | 54 | 59 | 57 | 55 | 50 | 44 | 52 | 39 | 31 | 23 | 16 | 12 | 13 | 15 | 17 | 16 | 20 | 23 | 29 | 26 | 35 | 36 | 49 | |
| 52 | 55 | 44 | 43 | 55 | 57 | 60 | 47 | 41 | 48 | 49 | 43 | 34 | 25 | 16 | 18 | 18 | 24 | 26 | 39 | 43 | 56 | 54 | 58 | 56 | |
| 57 | 41 | 51 | 50 | 45 | 45 | 41 | 48 | 38 | 35 | 40 | 47 | 51 | 55 | 48 | 41 | 45 | 43 | 51 | 51 | 46 | 44 | 44 | 40 | 40 | 1080 |
| 62 | 48 | 36 | 39 | 41 | 41 | 40 | 34 | 34 | 39 | 27 | 36 | 36 | 32 | 42 | 46 | 41 | 42 | 39 | 29 | 33 | 27 | 31 | 42 | 39 | 886 |
| 67 | 34 | 40 | 40 | 42 | 41 | 42 | 41 | 34 | 30 | 42 | 24 | 29 | 37 | 37 | 35 | 34 | 30 | 26 | 22 | 26 | 32 | 34 | 33 | 34 | 819 |
| 72 | 42 | 34 | 29 | 24 | 20 | 18 | 22 | 39 | 31 | 32 | 39 | 32 | 30 | 18 | 23 | 23 | 19 | 22 | 38 | 38 | 36 | 28 | 28 | 37 | 676 |
| 77 | 19 | 16 | 17 | 14 | 13 | 14 | 20 | 21 | 36 | 27 | 29 | 31 | 36 | 38 | 31 | 26 | 32 | 36 | 38 | 34 | 28 | 32 | 41 | 29 | 650 |
| 82 | 15 | 14 | 11 | 8 | 6 | 6 | 10 | 20 | 25 | 36 | 38 | 32 | 30 | 28 | 27 | 33 | 33 | 27 | 31 | 31 | 30 | 17 | 17 | 16 | 553 |
| 87 | 10 | 6 | 3 | 2 | 1 | 1 | 2 | 8 | 15 | 21 | 28 | 33 | 33 | 30 | 29 | 29 | 24 | 23 | 25 | 41 | 28 | 16 | 13 | 13 | 434 |
| 92 | | | | | | | | 1 | 7 | 13 | 19 | 23 | 33 | 34 | 34 | 33 | 34 | 35 | 38 | 31 | 15 | 13 | 9 | 2 | 370 |
| 97 | | | | | | | | | | 4 | 10 | 17 | 17 | 25 | 29 | 38 | 31 | 24 | 15 | 13 | 8 | 1 | | | 224 |
| 102 | | | | | | | | | | | 2 | 7 | 13 | 17 | 15 | 14 | 15 | 13 | 9 | | | | | | 107 |
| 107 | | | | | | | | | | | | | 1 | 3 | 11 | 12 | 7 | 1 | | | | | | | 35 |
| 112 | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| On Hours | 201 | 197 | 189 | 176 | 167 | 162 | 177 | 193 | 218 | 244 | 272 | 293 | 309 | 320 | 321 | 320 | 310 | 301 | 280 | 265 | 248 | 236 | 223 | 210 | 1723.00 |

**Chiller Replacement (Site 2671)**

| | |
|---|---|
| Program | Retrofit Efficiency Options Program |
| Measure | High Efficiency Water-Cooled Chiller |
| Site Description | College |

**Measure Description** Replace existing water-cooled chiller with an 80-ton high-efficiency water-cooled chiller.

**Summary of Ex Ante Impact Calculations** Tables of standard values were developed using the HBSSM simulation program based on climate zone, chiller size, building type, chiller efficiency, condenser water temperature, wet-bulb temperature, and cooling tower approach temperature. Values from these tables are used to calculate the rebate and associated impacts.

**Comments on PG&E Calculations** The application calculations used the correct business type, climate zone, chiller size, cooling tower approach temperature, chiller efficiency, and building size.

**Evaluation Process** The evaluation process consists of a review of the application form and supporting documentation, conducting an on-site survey and then computing impacts using the on-site data. Models are calibrated with actual weather, observed chiller run hours since the installation, chiller loading under extreme outdoor temperature conditions, chilled water temperature, and condenser water temperature. Energy impacts are based on typical weather data. A Title 24 baseline, nominal efficiency, and typical year bin weather data for the applicable climate zone are used in the bin analysis.

The on-site survey was conducted on August 9, 1999 in Coalinga (Climate Zone 13). Information on the retrofit equipment and operating conditions was collected through an inspection of the chiller and through an interview with the Director of Maintenance and Operations.

Discussions provided data for development of a relationship between chiller loading and outdoor dry bulb. The contact claimed that the chiller is available from 5:00 am to 10:00 pm, including summer. The chiller is brought on line at 70 degrees outside air temperature. The contact stated that the chiller is fully loaded at approximately 120 degrees F.

To compute the impacts, the following assumptions were used:

- Based on a water-cooled screw chiller less than 150 tons, a baseline Title 24 efficiency of 0.925 KW/ton was used.

Calibrating to weather data produced the following deviations from the claimed setpoints:

- A linear loading strategy was used for the analysis of both the baseline and rebated chillers, which assumed initial loading at 75 degrees and 100% loading at 120 degrees.

- The operating schedule for the chiller is from 5:00 am to 7:00 pm, Monday through Friday.

Chiller efficiencies at various temperatures were calculated from updated default performance coefficients provided in a memo to the California Energy Commission titled "1995 Proposed Changes to the ACM Manual Central Plant Cooling Equipment" by Mark Hydeman. These coefficients were used to develop a chiller efficiency curve for the Rebate case and a Title 24 base case. Both evaluation-based energy and demand impacts were lower than Ex Ante estimates. The primary source of the discrepancies is from the operating hours of the new chiller, which does not operate nearly as often or at as high a load as anticipated. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 15.15 | 67,159.68 | 0 |
| **Adjusted Engineering** | 5.23 | 6,456.60 | 0 |
| **Engineering Realization Rate** | 0.34 | 0.10 | N/A |

| Site 2671: Results | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 67,159 | 15.15 | | |
| QC | 6,457 | 5 | 8,159 | 10 |
| Realization Rate | 0.10 | 0.34 | 0.12 | 0.65 |

| Post-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.84 |
| Nom. Tons | 80 |
| nom kw | 67.2 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 122 | 0.00 | 80 | 0.886 | 0.00 | 0.00 | 0.00 | 0.00 |
| 117 | 0.00 | 73 | 0.879 | 0.00 | 0.00 | 0.00 | 0.00 |
| 112 | 0.00 | 65 | 0.877 | 0.00 | 0.00 | 0.00 | 0.00 |
| 107 | 5.00 | 58 | 0.885 | 257.39 | 51.48 | 28.00 | 1,441.37 |
| 102 | 96.00 | 51 | 0.905 | 4,421.08 | 46.05 | 92.00 | 4,236.86 |
| 97 | 216.00 | 44 | 0.943 | 8,889.32 | 41.15 | 149.00 | 6,131.99 |
| 92 | 331.00 | 36 | 1.028 | 12,371.67 | 37.38 | 213.00 | 7,961.22 |
| 87 | 356.00 | 29 | 1.150 | 11,914.58 | 33.47 | 215.00 | 7,195.61 |
| 82 | 410.00 | 22 | 1.379 | 12,338.46 | 30.09 | 266.00 | 8,004.95 |
| 77 | 407.00 | 15 | 1.838 | 10,881.25 | 26.74 | 294.00 | 7,860.17 |
| 72 | 0.00 | 7 | 3.302 | 0.00 | 0.00 | 0.00 | 0.00 |
| Totals | 1,816.00 | | | 60,816.36 | 51.48 | 1,257.00 | 42,832.17 |

| Title 24 Baseline Chiller | |
|---|---|
| Nom. Eff | 0.925 |
| Nom. Tons | 80 |
| nom kw | 74.021 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 122 | 0.00 | 80 | 0.976 | 0.00 | 0.00 |
| 117 | 0.00 | 73 | 0.968 | 0.00 | 0.00 |
| 112 | 0.00 | 65 | 0.966 | 0.00 | 0.00 |
| 107 | 5.00 | 58 | 0.975 | 283.51 | 56.70 |
| 102 | 96.00 | 51 | 0.996 | 4,869.83 | 50.73 |
| 97 | 216.00 | 44 | 1.039 | 9,791.62 | 45.33 |
| 92 | 331.00 | 36 | 1.132 | 13,627.44 | 41.17 |
| 87 | 356.00 | 29 | 1.267 | 13,123.96 | 36.87 |
| 82 | 410.00 | 22 | 1.519 | 13,590.86 | 33.15 |
| 77 | 407.00 | 15 | 2.025 | 11,985.74 | 29.45 |
| 72 | 0.00 | 7 | 3.637 | 0.00 | 0.00 |
| Totals | 1,821.00 | | | 67,272.96 | 56.70 |

| Pre-Retrofit Chiller | |
|---|---|
| Nom. Eff | 1 |
| Nom. Tons | 80 |
| nom kw | 80 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 122 | 0.00 | 80 | 1.055 | 0.00 | 0.00 | 0.00 | 0.00 |
| 117 | 0.00 | 73 | 1.046 | 0.00 | 0.00 | 0.00 | 0.00 |
| 112 | 0.00 | 65 | 1.044 | 0.00 | 0.00 | 0.00 | 0.00 |
| 107 | 5.00 | 58 | 1.053 | 306.41 | 61.28 | 28.00 | 1,715.92 |
| 102 | 96.00 | 51 | 1.077 | 5,263.19 | 54.82 | 92.00 | 5,043.89 |
| 97 | 216.00 | 44 | 1.123 | 10,582.53 | 48.99 | 149.00 | 7,299.98 |
| 92 | 331.00 | 36 | 1.224 | 14,728.17 | 44.50 | 213.00 | 9,477.65 |
| 87 | 356.00 | 29 | 1.370 | 14,184.03 | 39.84 | 215.00 | 8,566.20 |
| 82 | 410.00 | 22 | 1.642 | 14,688.64 | 35.83 | 266.00 | 9,529.70 |
| 77 | 407.00 | 15 | 2.188 | 12,953.87 | 31.83 | 294.00 | 9,357.34 |
| 72 | 0.00 | 7 | 3.930 | 0.00 | 0.00 | 0.00 | 0.00 |
| Totals | 1,821.00 | | | 72,706.84 | 61.28 | 1,257.00 | 50,990.68 |

Site 2671: Inputs to Model

| Parameter | Value Reported | Units of Parameter | Notes |
|---|---|---|---|
| Building Location | Coalinga | | |
| Climate Zone | 13 | | |
| | | | |
| Pre-Retrofit Chiller Nominal Capacity | 80 | Tons | Assumed |
| Pre-Retrofit Chiller Nominal Efficiency | 1 | kW/ton | Assumed |
| | | | |
| Post-Retrofit Chiller Nominal Capacity | 80 | Tons | Application |
| Post-Retrofit Chiller Nominal Efficiency | 0.84 | kW/ton | From Chiller Rating Sheet |
| Post-Retrofit Chiller Startup OSA Temperature | 70 | F | Contact provided estimate |
| Post-Retrofit Chiller Max Load OSA Temperature | 120 | F | Contact provided estimate |
| Post-Retrofit Chilled Water Supply Temperature Setpoint | 44 | F | Contact provided setpoints |
| Post-Retrofit Condenser Water Temperature Setpoint | 85 | F | Contact provided setpoints |
| | | | |
| Baseline Chiller Efficiency | 0.925 | kW/ton | Title 24 Nominal Efficiency for Chiller > 300 Tons |
| | | | |
| Chiller AM Lockout | 5:00 | AM | 24 hours per day, 7 days per week |
| Chiller PM Lockout | 10:00 | PM | 24 hours per day, 7 days per week |
| Post-Retrofit Compressor #1 Run Hours | 1158 | hours | Documented from Chiller Log |
| Post-Retrofit Compressor #2 Run Hours | 764 | hours | Documented from Chiller Log |
| Hours with both Compressors Operating Simultaneously | 51 | hours | Actual Hours at 107 and above |
| Post-Retrofit Chiller Run Hours | 1871 | hours | = Sum (Compressor #1 Run Hours, Compressor #2 Run Hours) - Simultaeous Hours |
| Date of Chiller Installation | 12/4/97 | | Contact provided estimate |
| Date at Run Hour Reading | 8/9/99 | | |
| Number of Days Chillers Operated | 614 | days | = ((Read Date - Install Date) * 5/7) - 10 Holidays |
| Average Hours per Year of Operation for Chiller | 1112.24 | Hours/Year | = Compressor #1 Average Hours per Year + Compressor #2 Average Hours per Year |
| Run Hours Since Install Using Actual Weather & Setpoints | 1907.00 | hours | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |
| Modeled Hours per Year from Actual Weather Data | 1257.00 | Hours/Year | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |

Site 2671: Post-Retrofit Chiller

| | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Screw Chiller (Water-Source) | | | | | | |
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

| | |
|---|---|
| Nom. Eff | 0.84 |
| Nom. Tons | 80 |
| nom kw | 67.2 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 122 | 80 | 85 | 42 | 77 | 1.000 | 1.03 | 1.03 | 0.2521 | 3.97 | 0.886 |
| 117 | 73 | 85 | 42 | 77 | 0.909 | 0.93 | 1.03 | 0.2499 | 4.00 | 0.879 |
| 112 | 65 | 85 | 42 | 77 | 0.818 | 0.83 | 1.03 | 0.2495 | 4.01 | 0.877 |
| 107 | 58 | 85 | 42 | 77 | 0.727 | 0.75 | 1.03 | 0.2516 | 3.97 | 0.885 |
| 102 | 51 | 85 | 42 | 77 | 0.636 | 0.67 | 1.03 | 0.2573 | 3.89 | 0.905 |
| 97 | 44 | 85 | 42 | 77 | 0.545 | 0.60 | 1.03 | 0.2682 | 3.73 | 0.943 |
| 92 | 36 | 85 | 41 | 76 | 0.455 | 0.53 | 1.04 | 0.2923 | 3.42 | 1.028 |
| 87 | 29 | 85 | 41 | 76 | 0.364 | 0.48 | 1.04 | 0.3272 | 3.06 | 1.150 |
| 82 | 22 | 85 | 41 | 76 | 0.273 | 0.43 | 1.04 | 0.3923 | 2.55 | 1.379 |
| 77 | 15 | 84 | 41 | 76 | 0.182 | 0.39 | 1.02 | 0.5228 | 1.91 | 1.838 |
| 72 | 7 | 83 | 41 | 77 | 0.091 | 0.36 | 1.01 | 0.9390 | 1.06 | 3.302 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625 | 0.00069 | 0.00028 | -0.00342 | 0.00025 | -0.00048 |
| EIRFPLR | 0.33019 | 0.23554 | 0.46071 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2671: Baseline Chiller

| Screw Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

| | |
|---|---|
| Nom. Eff | 0.925 |
| Nom. Tons | 80 |
| nom kw | 74.021 |

| Outdoor DB Temperature | Current Data: Tons Output | Current Data: Condenser Temp | Current Data: Supply temp | Calculated Values: Current Capacity | Calculated Values: Part Load Ratio | Calculated Values: Part Load Adjustment to EIR | Calculated Values: Ambient Adjustment to EIR | Efficiency: EIR | Efficiency: COP | Efficiency: kW/Ton |
|---|---|---|---|---|---|---|---|---|---|---|
| 122 | 80 | 85 | 42 | 77 | 1.000 | 1.03 | 1.03 | 0.2777 | 3.60 | 0.976 |
| 117 | 73 | 85 | 42 | 77 | 0.909 | 0.93 | 1.03 | 0.2753 | 3.63 | 0.968 |
| 112 | 65 | 85 | 42 | 77 | 0.818 | 0.83 | 1.03 | 0.2749 | 3.64 | 0.966 |
| 107 | 58 | 85 | 42 | 77 | 0.727 | 0.75 | 1.03 | 0.2772 | 3.61 | 0.975 |
| 102 | 51 | 85 | 42 | 77 | 0.636 | 0.67 | 1.03 | 0.2834 | 3.53 | 0.996 |
| 97 | 44 | 85 | 42 | 77 | 0.545 | 0.60 | 1.03 | 0.2955 | 3.38 | 1.039 |
| 92 | 36 | 85 | 41 | 76 | 0.455 | 0.53 | 1.04 | 0.3220 | 3.11 | 1.132 |
| 87 | 29 | 85 | 41 | 76 | 0.364 | 0.48 | 1.04 | 0.3604 | 2.77 | 1.267 |
| 82 | 22 | 85 | 41 | 76 | 0.273 | 0.43 | 1.04 | 0.4321 | 2.31 | 1.519 |
| 77 | 15 | 84 | 41 | 76 | 0.182 | 0.39 | 1.02 | 0.5758 | 1.74 | 2.025 |
| 72 | 7 | 83 | 41 | 77 | 0.091 | 0.36 | 1.01 | 1.0343 | 0.97 | 3.637 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625 | 0.00069 | 0.00028 | -0.00342 | 0.00025 | -0.00048 |
| EIRFPLR | 0.33019 | 0.23554 | 0.46071 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2671: Pre-Retrofit Chiller

| Screw Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| Part Load Efficiency (PLR) | 0.33018833 | 0.23554291 | 0.46070828 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.66625403 | 0.00068584 | 0.00028498 | -0.00341677 | 0.00025484 | -0.00048195 |

| | |
|---|---|
| Nom. Eff | 1 |
| Nom. Tons | 80 |
| nom kw | 80 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 122 | 80 | 85 | 42 | 77 | 1.000 | 1.03 | 1.03 | 0.3001 | 3.33 | 1.055 |
| 117 | 73 | 85 | 42 | 77 | 0.909 | 0.93 | 1.03 | 0.2975 | 3.36 | 1.046 |
| 112 | 65 | 85 | 42 | 77 | 0.818 | 0.83 | 1.03 | 0.2971 | 3.37 | 1.044 |
| 107 | 58 | 85 | 42 | 77 | 0.727 | 0.75 | 1.03 | 0.2996 | 3.34 | 1.053 |
| 102 | 51 | 85 | 42 | 77 | 0.636 | 0.67 | 1.03 | 0.3063 | 3.26 | 1.077 |
| 97 | 44 | 85 | 42 | 77 | 0.545 | 0.60 | 1.03 | 0.3193 | 3.13 | 1.123 |
| 92 | 36 | 85 | 41 | 76 | 0.455 | 0.53 | 1.04 | 0.3480 | 2.87 | 1.224 |
| 87 | 29 | 85 | 41 | 76 | 0.364 | 0.48 | 1.04 | 0.3895 | 2.57 | 1.370 |
| 82 | 22 | 85 | 41 | 76 | 0.273 | 0.43 | 1.04 | 0.4670 | 2.14 | 1.642 |
| 77 | 15 | 84 | 41 | 76 | 0.182 | 0.39 | 1.02 | 0.6223 | 1.61 | 2.188 |
| 72 | 7 | 83 | 41 | 77 | 0.091 | 0.36 | 1.01 | 1.1179 | 0.89 | 3.930 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | 0.58531422 | 0.01539593 | 0.00007296 | -0.00212462 | -0.00000715 | -0.00004597 |
| EIRFT | 0.66625 | 0.00069 | 0.00028 | -0.00342 | 0.00025 | -0.00048 |
| EIRFPLR | 0.33019 | 0.23554 | 0.46071 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2671: Weather Data

TMY temperature data

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23.00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | . | . | . | . | 1 | 3 | 3 | . | . | . | | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 32 | 4 | 6 | 10 | 14 | 15 | 19 | 19 | 7 | . | . | | . | . | . | . | . | . | . | . | . | 2 | 4 | 4 | 4 | |
| 37 | 27 | 32 | 34 | 34 | 37 | 32 | 31 | 26 | 17 | 8 | 1 | . | . | . | | . | . | 2 | 5 | 7 | 6 | 9 | 17 | 26 | |
| 42 | 41 | 40 | 36 | 41 | 37 | 42 | 43 | 34 | 24 | 19 | 13 | 8 | 3 | 3 | 3 | 3 | 5 | 7 | 10 | 19 | 27 | 31 | 32 | 32 | |
| 47 | 50 | 54 | 64 | 65 | 65 | 55 | 48 | 45 | 38 | 24 | 20 | 15 | 11 | 9 | 9 | 8 | 14 | 19 | 29 | 26 | 33 | 42 | 49 | 50 | |
| 52 | 61 | 61 | 61 | 59 | 56 | 53 | 49 | 48 | 49 | 49 | 41 | 35 | 25 | 24 | 21 | 23 | 30 | 45 | 41 | 59 | 58 | 60 | 56 | 55 | |
| 57 | 43 | 42 | 41 | 44 | 48 | 42 | 38 | 39 | 36 | 39 | 46 | 46 | 42 | 41 | 41 | 39 | 42 | 42 | 49 | 43 | 47 | 37 | 44 | 50 | |
| 62 | 35 | 44 | 52 | 63 | 55 | 46 | 39 | 36 | 37 | 35 | 36 | 37 | 39 | 38 | 43 | 37 | 41 | 36 | 40 | 38 | 36 | 40 | 29 | 33 | |
| 67 | 53 | 52 | 40 | 21 | 33 | 47 | 48 | 39 | 37 | 31 | 26 | 27 | 36 | 39 | 31 | 36 | 33 | 32 | 28 | 25 | 22 | 28 | 39 | 39 | |
| 72 | 33 | 26 | 22 | 23 | 17 | 20 | 27 | 41 | 42 | 37 | 33 | 33 | 26 | 23 | 27 | 25 | 24 | 27 | 25 | 32 | 33 | 37 | 47 | 42 | |
| 77 | 15 | 8 | 5 | 1 | 1 | 6 | 18 | 35 | 39 | 41 | 39 | 36 | 29 | 30 | 27 | 26 | 25 | 24 | 32 | 30 | 43 | 42 | 29 | 25 | 407 |
| 82 | 3 | . | . | . | . | . | 2 | 13 | 33 | 45 | 44 | 35 | 39 | 36 | 35 | 35 | 30 | 35 | 28 | 38 | 39 | 27 | 18 | 9 | 410 |
| 87 | . | . | . | . | . | . | . | 2 | 12 | 31 | 38 | 42 | 39 | 31 | 27 | 29 | 36 | 27 | 42 | 36 | 17 | 8 | 1 | . | 356 |
| 92 | . | . | . | . | . | . | . | . | 1 | 6 | 25 | 36 | 37 | 39 | 42 | 43 | 39 | 37 | 26 | 12 | 2 | . | . | . | 331 |
| 97 | . | . | . | . | . | . | . | . | . | . | 3 | 15 | 31 | 36 | 36 | 31 | 27 | 27 | 10 | . | . | . | . | . | 216 |
| 102 | . | . | . | . | . | . | . | . | . | . | . | . | 8 | 15 | 22 | 27 | 19 | 5 | . | . | . | . | . | . | 96 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 3 | . | . | . | . | . | . | . | . | 5 |
| 112 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| 117 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| 122 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| On Hours for Comp #1 | | | | | | 26 | 47 | 91 | 127 | 160 | 182 | 197 | 209 | 211 | 217 | 219 | 200 | 182 | 163 | 148 | 134 | 114 | | | 1300.71 |

Note: Total "On Hours" value has been scaled by 5/7 to account for M-F operation only

Actual temperature by hour from 08/10/98 to 08/09/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4.00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14.00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20.00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | . | . | . | 1 | 1 | 1 | 2 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 27 | 2 | 2 | 2 | 1 | 1 | 1 | . | 1 | 2 | 1 | 1 | . | . | . | . | . | . | . | . | . | 1 | 1 | 2 | 3 | |
| 32 | 4 | 4 | 10 | 11 | 10 | 14 | 13 | 11 | 8 | 3 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | |
| 37 | 14 | 17 | 12 | 16 | 19 | 20 | 22 | 21 | 15 | 11 | 10 | 8 | 4 | 3 | 3 | 3 | 3 | 4 | 5 | 7 | 8 | 11 | 11 | 10 | |
| 42 | 21 | 25 | 28 | 27 | 30 | 28 | 29 | 19 | 16 | 12 | 5 | 3 | 7 | 6 | 5 | 4 | 6 | 6 | 6 | 8 | 11 | 13 | 19 | 20 | |
| 47 | 35 | 37 | 37 | 35 | 34 | 32 | 29 | 36 | 29 | 27 | 17 | 11 | 6 | 6 | 8 | 8 | 8 | 11 | 16 | 21 | 21 | 28 | 26 | 35 | |
| 52 | 35 | 27 | 30 | 36 | 38 | 41 | 30 | 25 | 28 | 29 | 33 | 28 | 21 | 12 | 12 | 12 | 18 | 21 | 30 | 32 | 39 | 36 | 40 | 39 | |
| 57 | 28 | 38 | 38 | 36 | 37 | 35 | 41 | 29 | 27 | 28 | 28 | 34 | 37 | 33 | 28 | 34 | 32 | 34 | 34 | 29 | 27 | 28 | 25 | 22 | |
| 62 | 31 | 28 | 27 | 26 | 27 | 24 | 24 | 26 | 27 | 17 | 27 | 24 | 21 | 31 | 34 | 28 | 28 | 26 | 19 | 22 | 19 | 18 | 29 | 32 | |
| 67 | 23 | 23 | 25 | 26 | 26 | 28 | 24 | 25 | 24 | 33 | 14 | 19 | 29 | 26 | 22 | 22 | 21 | 20 | 17 | 18 | 24 | 30 | 27 | 24 | |
| 72 | 26 | 25 | 23 | 22 | 16 | 15 | 18 | 24 | 21 | 22 | 31 | 23 | 11 | 10 | 16 | 16 | 12 | 13 | 21 | 25 | 27 | 20 | 16 | 25 | |
| 77 | 17 | 14 | 12 | 9 | 10 | 10 | 12 | 15 | 22 | 17 | 19 | 21 | 27 | 28 | 23 | 20 | 24 | 30 | 26 | 22 | 19 | 20 | 29 | 21 | 294 |
| 82 | 11 | 10 | 9 | 8 | 6 | 6 | 10 | 14 | 20 | 26 | 25 | 24 | 21 | 19 | 20 | 24 | 25 | 16 | 16 | 17 | 18 | 26 | 12 | 9 | 266 |
| 87 | 9 | 6 | 3 | 2 | 1 | 1 | 2 | 8 | 10 | 18 | 21 | 22 | 22 | 23 | 19 | 19 | 15 | 18 | 17 | 26 | 21 | 10 | 10 | 12 | 215 |
| 92 | . | | . | . | . | . | . | 1 | 7 | 8 | 14 | 19 | 22 | 22 | 23 | 22 | 23 | 24 | 28 | 14 | 12 | 12 | 8 | 2 | 213 |
| 97 | . | | . | . | . | . | . | . | . | 4 | 8 | 11 | 14 | 19 | 21 | 22 | 22 | 18 | 10 | 12 | 7 | 1 | . | . | 149 |
| 102 | . | . | . | . | . | . | . | . | . | . | 2 | 7 | 12 | 13 | 13 | 12 | 12 | 12 | 9 | . | . | . | . | . | 92 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 3 | 8 | 9 | 6 | 1 | . | . | . | . | . | . | 28 |
| 112 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| 117 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| 122 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| On Hours for Comp #1 | | | | | | 32 | 42 | 62 | 80 | 95 | 120 | 127 | 130 | 137 | 143 | 144 | 139 | 132 | 127 | 116 | 104 | 89 | | | 1257.00 |

Actual temperature by hour from 04/01/98 to 08/09/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14.00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | . | . | . | 1 | 1 | 1 | 2 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | |
| 27 | 2 | 2 | 2 | 1 | 1 | 1 | . | 1 | 2 | 1 | 1 | . | . | . | . | . | . | . | . | . | 1 | 1 | 2 | 3 | |
| 32 | 6 | 6 | 14 | 16 | 15 | 19 | 19 | 17 | 11 | 4 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 3 | 2 | 2 | 2 | 3 | |
| 37 | 21 | 25 | 19 | 22 | 27 | 28 | 29 | 27 | 25 | 18 | 14 | 9 | 4 | 3 | 3 | 3 | 3 | 4 | 5 | 7 | 10 | 15 | 18 | 18 | |
| 42 | 37 | 41 | 45 | 52 | 55 | 53 | 55 | 44 | 27 | 25 | 15 | 11 | 12 | 7 | 5 | 4 | 7 | 8 | 11 | 17 | 23 | 25 | 34 | 33 | |
| 47 | 65 | 68 | 70 | 61 | 62 | 59 | 54 | 54 | 51 | 41 | 28 | 25 | 18 | 18 | 19 | 19 | 23 | 30 | 38 | 45 | 43 | 50 | 49 | 65 | |
| 52 | 62 | 53 | 54 | 66 | 66 | 71 | 58 | 51 | 50 | 55 | 57 | 46 | 43 | 36 | 32 | 38 | 39 | 44 | 52 | 54 | 65 | 69 | 70 | 61 | |
| 57 | 50 | 64 | 65 | 62 | 63 | 58 | 60 | 52 | 50 | 48 | 55 | 61 | 61 | 54 | 52 | 52 | 57 | 57 | 61 | 51 | 46 | 46 | 44 | 51 | |
| 62 | 48 | 45 | 51 | 47 | 47 | 45 | 42 | 40 | 48 | 38 | 40 | 38 | 40 | 53 | 57 | 53 | 47 | 44 | 31 | 39 | 40 | 38 | 49 | 48 | |
| 67 | 42 | 39 | 33 | 32 | 33 | 37 | 38 | 43 | 34 | 46 | 35 | 39 | 46 | 37 | 32 | 31 | 32 | 32 | 33 | 38 | 40 | 43 | 39 | 40 | |
| 72 | 31 | 32 | 32 | 34 | 30 | 28 | 26 | 33 | 39 | 34 | 40 | 36 | 23 | 27 | 35 | 33 | 28 | 29 | 33 | 33 | 34 | 31 | 32 | 35 | |
| 77 | 29 | 26 | 22 | 18 | 16 | 15 | 26 | 24 | 28 | 30 | 34 | 30 | 37 | 39 | 34 | 33 | 36 | 40 | 34 | 29 | 32 | 32 | 36 | 30 | 440 |
| 82 | 20 | 16 | 14 | 12 | 9 | 10 | 14 | 25 | 31 | 37 | 35 | 39 | 33 | 27 | 26 | 28 | 31 | 22 | 28 | 32 | 28 | 33 | 24 | 18 | 386 |
| 87 | 13 | 9 | 5 | 2 | 1 | 1 | 3 | 13 | 19 | 27 | 30 | 31 | 31 | 36 | 33 | 34 | 28 | 31 | 28 | 31 | 32 | 22 | 14 | 18 | 345 |
| 92 | . | . | . | . | . | . | . | 1 | 11 | 15 | 24 | 28 | 33 | 30 | 32 | 31 | 32 | 30 | 35 | 29 | 18 | 16 | 12 | 3 | 302 |
| 97 | . | . | . | . | . | . | . | . | . | 7 | 14 | 20 | 24 | 30 | 29 | 29 | 30 | 30 | 20 | 15 | 12 | 3 | 1 | . | 233 |
| 102 | . | . | . | . | . | . | . | . | . | . | 3 | 10 | 18 | 20 | 24 | 23 | 22 | 19 | 14 | 3 | . | . | . | . | 153 |
| 107 | . | . | . | . | . | . | . | . | . | . | . | 1 | 2 | 7 | 11 | 13 | 9 | 4 | 1 | . | . | . | . | . | 48 |
| 112 | . | . | | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | . | . | . | . | . | . | . | 3 |
| 117 | . | . | | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| 122 | . | . | | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 0 |
| On Hours for Comp #1 | | | | | | 54 | 69 | 96 | 128 | 150 | 180 | 195 | 201 | 216 | 224 | 224 | 216 | 205 | 193 | 172 | 156 | 137 | | | 1907.00 |

**Customized Space Conditioning (Site 2766)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | Space Conditioning (Customized) |
| Site Description | Office |

**Measure Description** Replace two chillers, increase cooling tower capacity, install a primary/secondary chilled water loop with a variable speed drive (VSD) on the secondary loop.

**Summary of Ex Ante Impact Calculations** Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and all HVAC plant and system characteristics.

**Comments on PG&E Calculations** The correct climate zone, building characteristics, and HVAC plant and system characteristics were used in the application.

**Evaluation Process** The evaluation process consisted of reviewing the application form and supporting documentation. Several attempts were made to schedule an on-site audit. The telephone number supplied in the MDSS is never answered, and a thorough search to locate an alternate number proved unsuccessful as well. Due to the difficulties associated with this site, a thorough review of the application was conducted. Ex ante impact estimates are accepted as accurate.

**Additional Notes**

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 145 | 288,259.81 | 0 |
| **Adjusted Engineering** | 145 | 288,259.81 | 0 |
| **Engineering Realization Rate** | 1.00 | 1.00 | N/A |

**Plate & Frame Heat Exchanger (Site 2771)**

| | |
|---|---|
| Program | Advanced Performance Options Program |
| Measure | Install a Plate & Frame Heat Exchanger |
| Site Description | Office |

**Measure Description** Install a plate & frame heat exchanger to utilize free cooling when available.

**Summary of Ex Ante Impact Calculations** Impacts were developed using DOE2.1E simulation program based on climate zone, building type, chiller and cooling tower characteristics.

**Comments on PG&E Calculations** The correct climate zone, heat exchanger characteristics, chiller size category and building characteristics were used in the application calculations. The application appears to have over-estimated the usage of the post-retrofit chillers, resulting in a modest over-estimation of impact. The most likely source of error is the loading and staging strategy for the heat exchanger and chillers.

**Evaluation Process** The evaluation process consists of a review of the application form and supporting documentation, conducting an on-site survey and then computing impacts using the on-site data.

The on-site survey was conducted on August 16, 1999 in San Francisco (Climate Zone 3). Information on the retrofit equipment and operating conditions was collected through an inspection of the chillers and heat exchanger and through an interview with the Building Engineer.

The interview and supplied data provided was used to develop a relationship between heat exchanger and chiller loading and outdoor dry bulb. The staging strategy for the plant provided by the contact varied seasonally. The heat exchanger operates roughly from 45 to 60 degrees F dry bulb outside air temperature. During the summer months, the 511-ton chiller is the lead chiller and during all other months the 285-ton chiller is the lead. The lockout times are from 6:00 pm to 6:00 am on weekdays. The plant is locked out on weekends. The contact claims that the plant is fully loaded between 87 and 92 degrees F outside air temperature.

Models are calibrated with actual weather, observed chiller run hours before and after the installation, heat exchanger and chiller staging strategy supplied by the contact, chilled water temperatures, and condenser water temperatures. Energy impacts are based on typical weather data. For this analysis, the baseline consists of their existing chillers without the heat exchanger because there is no Title 24 baseline for heat exchangers. This information, along with the chillers' efficiencies, and typical year bin weather data for the applicable climate zone is used in the bin analysis. To compute the impacts, the following assumptions were used:

- The heat exchanger operates when the dry bulb outside air temperature is between 45 and 60 degrees F.

- The baseline for the heat exchanger is the pre-retrofit chiller plant.
- Initial chiller loading begins at 65 degrees F and the plant is fully loaded at 90 degrees F outside air temperature.

Chiller efficiencies at various temperatures were calculated from updated default performance coefficients provided in a memo to the California Energy Commission titled "1995 Proposed Changes to the ACM Manual Central Plant Cooling Equipment" by Mark Hydeman. These coefficients were used to develop a chiller efficiency curve for the Rebate case and a Title 24 base case. Evaluation-based energy impacts are higher than Ex Ante estimates. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

Building occupancy has increased since the rebate application was completed, therefore more cooling is required than originally specified. This results in higher impacts due to the increased operation of the cooling equipment.

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 0 | 230,772.28 | 0 |
| **Adjusted Engineering** | 0 | 305,851.43 | 0 |
| **Engineering Realization Rate** | N/A | 1.33 | N/A |

Site 2771: Results

| Total Impacts | Energy | Demand |
|---|---|---|
| MDSS | 230,772 | 0 |
| QC | 305,851 | 0 |
| Realization Rate | 1.33 | - |

| Other Season Impacts | Energy | Demand |
|---|---|---|
| MDSS | 230,772 | 0 |
| QC | 210,670 | 0 |
| Realization Rate | 0.91 | - |

| Summer Impacts | Energy | Demand |
|---|---|---|
| MDSS | 230,772 | 0 |
| QC | 95,181 | 0 |
| Realization Rate | 0.41 | - |

Site 2771: Other Season Results

| Impacts | Energy | Demand |
|---|---|---|
| MDSS | 230,772 | 0 |
| QC | 210,670 | 0 |
| Realization Rate | 0.91 | - |

| Baseline Chiller #1 | |
|---|---|
| Nom. Eff | 0.880 |
| Nom. Tons | 285 |
| nom kw | 250.800 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 97 | 0.00 | 285 | 0.81 | 0.00 | 229.81 |
| 92 | 0.00 | 285 | 0.81 | 0.00 | 230.21 |
| 87 | 15.00 | 142.5 | 0.85 | 1,821.03 | 121.40 |
| 82 | 29.00 | 0 | 0.00 | 0.00 | 0.00 |
| 77 | 71.00 | 0 | 0.00 | 0.00 | 0.00 |
| 72 | 172.00 | 285 | 0.81 | 39,829.58 | 231.57 |
| 67 | 368.00 | 142.5 | 0.86 | 44,918.03 | 122.06 |
| 62 | 711.00 | 114 | 0.91 | 73,606.94 | 103.53 |
| 57 | 956.00 | 85.5 | 1.01 | 82,262.67 | 86.05 |
| 52 | 592.00 | 57 | 1.22 | 41,225.43 | 69.64 |
| 47 | 250.00 | 28.5 | 1.91 | 13,575.10 | 54.30 |
| Totals | 3,164.00 | | | 297,238.78 | 231.57 |

| Post-Retrofit Chiller #1 | |
|---|---|
| Nom. Eff | 0.88 |
| Nom. Tons | 285 |
| nom kw | 250.8 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 97 | 0.00 | 285 | 0.81 | 0.00 | 229.81 | 0.00 | 0.00 |
| 92 | 0.00 | 285 | 0.81 | 0.00 | 230.21 | 0.00 | 0.00 |
| 87 | 15.00 | 142.5 | 0.85 | 1,821.03 | 121.40 | 6.00 | 728.41 |
| 82 | 29.00 | 0 | 0.00 | 0.00 | 0.00 | 45.00 | 0.00 |
| 77 | 71.00 | 0 | 0.00 | 0.00 | 0.00 | 42.00 | 0.00 |
| 72 | 172.00 | 285 | 0.81 | 39,829.58 | 231.57 | 52.00 | 12,041.50 |
| 67 | 368.00 | 142.5 | 0.86 | 44,918.03 | 122.06 | 202.00 | 24,656.09 |
| 62 | 711.00 | 0 | 0.00 | 0.00 | 0.00 | 452.00 | 0.00 |
| 57 | 956.00 | 0 | 0.00 | 0.00 | 0.00 | 677.00 | 0.00 |
| 52 | 592.00 | 0 | 0.00 | 0.00 | 0.00 | 490.00 | 0.00 |
| 47 | 250.00 | 0 | 0.00 | 0.00 | 0.00 | 225.00 | 0.00 |
| Totals | 3,164.00 | | | 86,568.64 | 231.57 | 2,191.00 | 37,426.01 |

| Baseline Chiller #2 | |
|---|---|
| Nom. Eff | 0.730 |
| Nom. Tons | 511 |
| nom kw | 373.030 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 97 | 0.00 | 511 | 0.67 | 0.00 | 341.81 |
| 92 | 0.00 | 511 | 0.67 | 0.00 | 342.41 |
| 87 | 15.00 | 511 | 0.67 | 5,144.59 | 342.97 |
| 82 | 29.00 | 383.25 | 0.67 | 7,454.69 | 257.06 |
| 77 | 71.00 | 255.5 | 0.71 | 12,857.97 | 181.10 |
| 72 | 172.00 | 127.75 | 0.90 | 19,807.78 | 115.16 |
| 67 | 368.00 | 0 | 0.00 | 0.00 | 0.00 |
| 62 | 711.00 | 0 | 0.00 | 0.00 | 0.00 |
| 57 | 956.00 | 0 | 0.00 | 0.00 | 0.00 |
| 52 | 592.00 | 0 | 0.00 | 0.00 | 0.00 |
| 47 | 250.00 | 0 | 0.00 | 0.00 | 0.00 |
| Totals | 3,164.00 | | | 45,265.02 | 342.97 |

| Post-Retrofit Chiller #2 | |
|---|---|
| Nom. Eff | 0.73 |
| Nom. Tons | 511 |
| nom kw | 373.03 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 97 | 0.00 | 511 | 0.67 | 0.00 | 341.81 | 0.00 | 0.00 |
| 92 | 0.00 | 511 | 0.67 | 0.00 | 342.41 | 0.00 | 0.00 |
| 87 | 15.00 | 511 | 0.67 | 5,144.59 | 342.97 | 6.00 | 2,057.84 |
| 82 | 29.00 | 383.25 | 0.67 | 7,454.69 | 257.06 | 45.00 | 11,567.62 |
| 77 | 71.00 | 255.5 | 0.71 | 12,857.97 | 181.10 | 42.00 | 7,606.12 |
| 72 | 172.00 | 127.75 | 0.90 | 19,807.78 | 115.16 | 52.00 | 5,988.40 |
| 67 | 368.00 | 0 | 0.00 | 0.00 | 0.00 | 202.00 | 0.00 |
| 62 | 711.00 | 0 | 0.00 | 0.00 | 0.00 | 452.00 | 0.00 |
| 57 | 956.00 | 0 | 0.00 | 0.00 | 0.00 | 677.00 | 0.00 |
| 52 | 592.00 | 0 | 0.00 | 0.00 | 0.00 | 490.00 | 0.00 |
| 47 | 250.00 | 0 | 0.00 | 0.00 | 0.00 | 225.00 | 0.00 |
| Totals | 3,164.00 | | | 45,265.02 | 342.97 | 2,191.00 | 27,219.97 |

Site 2771: Summer Results

| Impacts | Energy | Demand |
|---|---|---|
| MDSS | 230,772 | 0 |
| QC | 95,181 | 0 |
| Realization Rate | 0.41 | - |

| Baseline Chiller #1 | |
|---|---|
| Nom. Eff | 0.880 |
| Nom. Tons | 285 |
| nom kw | 250.800 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 97 | 0.00 | 285 | 0.81 | 0.00 | 229.81 |
| 92 | 1.00 | 285 | 0.81 | 230.21 | 230.21 |
| 87 | 13.00 | 142.5 | 0.85 | 1,578.23 | 121.40 |
| 82 | 29.00 | 0 | 0.00 | 0.00 | 0.00 |
| 77 | 104.00 | 0 | 0.00 | 0.00 | 0.00 |
| 72 | 225.00 | 0 | 0.00 | 0.00 | 0.00 |
| 67 | 322.00 | 0 | 0.00 | 0.00 | 0.00 |
| 62 | 259.00 | 0 | 0.00 | 0.00 | 0.00 |
| 57 | 131.00 | 0 | 0.00 | 0.00 | 0.00 |
| 52 | 20.00 | 0 | 0.00 | 0.00 | 0.00 |
| 47 | 0.00 | 0 | 0.00 | 0.00 | 0.00 |
| Totals | 1,104.00 | | | 1,808.44 | 230.21 |

| Post-Retrofit Chiller #1 | |
|---|---|
| Nom. Eff | 0.88 |
| Nom. Tons | 285 |
| nom kw | 250.8 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 97 | 0.00 | 285 | 0.81 | 0.00 | 229.81 | 0.00 | 0.00 |
| 92 | 1.00 | 285 | 0.81 | 230.21 | 230.21 | 1.00 | 230.21 |
| 87 | 13.00 | 142.5 | 0.85 | 1,578.23 | 121.40 | 12.00 | 1,456.82 |
| 82 | 29.00 | 0 | 0.00 | 0.00 | 0.00 | 20.00 | 0.00 |
| 77 | 104.00 | 0 | 0.00 | 0.00 | 0.00 | 55.00 | 0.00 |
| 72 | 225.00 | 0 | 0.00 | 0.00 | 0.00 | 125.00 | 0.00 |
| 67 | 322.00 | 0 | 0.00 | 0.00 | 0.00 | 212.00 | 0.00 |
| 62 | 259.00 | 0 | 0.00 | 0.00 | 0.00 | 257.00 | 0.00 |
| 57 | 131.00 | 0 | 0.00 | 0.00 | 0.00 | 98.00 | 0.00 |
| 52 | 20.00 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 47 | 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Totals | 1,104.00 | | | 1,808.44 | 230.21 | 780.00 | 1,687.04 |

| Baseline Chiller #2 | |
|---|---|
| Nom. Eff | 0.730 |
| Nom. Tons | 511 |
| nom kw | 373.030 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 97 | 0.00 | 511 | 0.67 | 0.00 | 341.81 |
| 92 | 1.00 | 511 | 0.67 | 342.41 | 342.41 |
| 87 | 13.00 | 511 | 0.67 | 4,458.65 | 342.97 |
| 82 | 29.00 | 511 | 0.67 | 9,961.35 | 343.49 |
| 77 | 104.00 | 409 | 0.67 | 28,486.95 | 273.91 |
| 72 | 225.00 | 357.7 | 0.68 | 54,371.11 | 241.65 |
| 67 | 322.00 | 306.6 | 0.69 | 67,916.27 | 210.92 |
| 62 | 259.00 | 255.5 | 0.71 | 47,070.98 | 181.74 |
| 57 | 131.00 | 204.4 | 0.75 | 20,190.74 | 154.13 |
| 52 | 20.00 | 153.3 | 0.84 | 2,561.88 | 128.09 |
| 47 | 0.00 | 102.2 | 1.01 | 0.00 | 103.65 |
| Totals | 1,104.00 | | | 235,360.34 | 343.49 |

| Post-Retrofit Chiller #2 | |
|---|---|
| Nom. Eff | 0.73 |
| Nom. Tons | 511 |
| nom kw | 373.03 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 97 | 0.00 | 511 | 0.67 | 0.00 | 341.81 | 0.00 | 0.00 |
| 92 | 1.00 | 511 | 0.67 | 342.41 | 342.41 | 1.00 | 342.41 |
| 87 | 13.00 | 511 | 0.67 | 4,458.65 | 342.97 | 12.00 | 4,115.67 |
| 82 | 29.00 | 511 | 0.67 | 9,961.35 | 343.49 | 20.00 | 6,869.90 |
| 77 | 104.00 | 409 | 0.67 | 28,486.95 | 273.91 | 55.00 | 15,065.21 |
| 72 | 225.00 | 306.6 | 0.69 | 47,400.99 | 210.67 | 125.00 | 26,333.88 |
| 67 | 322.00 | 204.4 | 0.75 | 49,528.70 | 153.82 | 212.00 | 32,608.96 |
| 62 | 259.00 | 0 | 0.00 | 0.00 | 0.00 | 257.00 | 0.00 |
| 57 | 131.00 | 0 | 0.00 | 0.00 | 0.00 | 98.00 | 0.00 |
| 52 | 20.00 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 47 | 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Totals | 1,104.00 | | | 140,179.05 | 343.49 | 780.00 | 85,336.04 |

Site 2771: Inputs to Model

| Parameter | Value Reported | Units of Parameter | Notes |
|---|---|---|---|
| Chiller #1 Nominal Capacity | 285 | Tons | Application |
| Chiller #1 Nominal Efficiency | 0.88 | kW/ton | Application |
| Post-Retrofit Chiller #1 Startup OSA Temperature | 60 | F | Contact provided estimate |
| Post-Retrofit Chiller #1 Max Load OSA Temperature | 73 | F | Contact provided estimate |
| Post-Retrofit Chiller #1 Chilled Water Supply Temperature Setpoint | 60 | F | When OSA = 60 |
| Post-Retrofit Chiller #1 Chilled Water Supply Temperature Setpoint | 42 | F | When OSA = 80 |
| Post-Retrofit Chiller #1 Condenser Water Temperature Setpoint | 85 | F | Contact provided setpoints |
| | | | |
| | | | |
| Pre-Retrofit Chiller #2 Nominal Capacity | 511 | Tons | Application |
| Pre-Retrofit Chiller #2 Nominal Efficiency | 0.73 | kW/ton | Application |
| Post-Retrofit Chiller #2 Startup OSA Temperature | 73 | F | Contact provided estimate |
| Post-Retrofit Chiller #2 Max Load OSA Temperature | 87 | F | Contact provided estimate |
| Post-Retrofit Chiller #2 Chilled Water Supply Temperature Setpoint | 42 | F | Contact provided setpoints |
| Post-Retrofit Chiller #2 Condenser Water Temperature Setpoint | 85 | F | Contact provided setpoints |
| | | | |
| Chiller AM Lockout | 6:00 | AM | 24 hours per day, 7 days per week |
| Chiller PM Lockout | 6:00 | PM | 24 hours per day, 7 days per week |
| Post-Retrofit Chiller #1 Run Hours | | hours | Documented from Chiller Log |
| Post-Retrofit Chiller #2 Run Hours | | hours | Documented from Chiller Log |
| Total Post-Retrofit Chiller Run Hours | 0 | hours | = Chiller #2 Run Hours + Chiller #3 Run Hours |
| Date of Heat Exchanger Installation | 11/1/97 | | Best guess from contact (Oct or Nov '97) |
| Date at Run Hour Reading | 8/16/99 | | |
| Number of Days Chillers Operated | 654 | days | = ((Read Date - Install Date) * 5/7) - 10 Holidays |
| Average Hours per Year of Operation for Chiller #1 | 936.00 | Hours/Year | = (Run Hours for New Chiller / Number of Days Chiller Operated) * 365 Days/Year |
| Chiller #3 Run Hours Since Install Using Actual Weather & Setpoints | 2436.00 | hours | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |
| Chiller #3 Modeled Hours per Year from Actual Weather Data | 772.00 | Hours/Year | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |

Site 2771: Post-Retrofit Chiller #1, Other Months

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.88 |
| Nom. Tons | 285 |
| nom kw | 250.8 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 97 | 285 | 85 | 49 | 284 | 1.000 | 1.00 | 0.92 | 0.2293 | 4.36 | 0.806 |
| 92 | 285 | 84 | 48 | 284 | 1.000 | 1.00 | 0.92 | 0.2297 | 4.35 | 0.808 |
| 87 | 142.5 | 83 | 47 | 284 | 0.500 | 0.52 | 0.92 | 0.2423 | 4.13 | 0.852 |
| 82 | 0 | 82 | 46 | 284 | 0.000 | 0.17 | 0.92 | #DIV/0! | #DIV/0! | #DIV/0! |
| 77 | 0 | 81 | 45 | 284 | 0.000 | 0.17 | 0.92 | #DIV/0! | #DIV/0! | #DIV/0! |
| 72 | 285 | 80 | 44 | 283 | 1.000 | 1.00 | 0.93 | 0.2311 | 4.33 | 0.813 |
| 67 | 143 | 79 | 43 | 282 | 0.500 | 0.52 | 0.93 | 0.2436 | 4.10 | 0.857 |
| 62 | 0 | 78 | 42 | 281 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 57 | 0 | 77 | 41 | 279 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 52 | 0 | 76 | 40 | 277 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 47 | 0 | 75 | 39 | 275 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2771: Post-Retrofit Chiller #2, Other Months

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| Post-Retrofit Chiller #2 | |
|---|---|
| Nom. Eff | 0.73 |
| Nom. Tons | 511 |
| nom kw | 373.03 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 97 | 511 | 85 | 49 | 509 | 1.000 | 1.00 | 0.92 | 0.1902 | 5.26 | 0.669 |
| 92 | 511 | 84 | 48 | 509 | 1.000 | 1.00 | 0.92 | 0.1906 | 5.25 | 0.670 |
| 87 | 511 | 83 | 47 | 510 | 1.000 | 1.00 | 0.92 | 0.1909 | 5.24 | 0.671 |
| 82 | 383 | 82 | 46 | 509 | 0.750 | 0.75 | 0.92 | 0.1908 | 5.24 | 0.671 |
| 77 | 256 | 81 | 45 | 509 | 0.500 | 0.52 | 0.92 | 0.2016 | 4.96 | 0.709 |
| 72 | 127.75 | 80 | 44 | 508 | 0.250 | 0.33 | 0.93 | 0.2564 | 3.90 | 0.901 |
| 67 | 0 | 79 | 43 | 506 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 62 | 0 | 78 | 42 | 503 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 57 | 0 | 77 | 41 | 501 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 52 | 0 | 76 | 40 | 497 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 47 | 0 | 75 | 39 | 494 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2771: Baseline Chiller #1, Other Months

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.88 |
| Nom. Tons | 285 |
| nom kw | 250.8 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 97 | 285 | 85 | 49 | 284 | 1.000 | 1.00 | 0.92 | 0.2293 | 4.36 | 0.806 |
| 92 | 285 | 84 | 48 | 284 | 1.000 | 1.00 | 0.92 | 0.2297 | 4.35 | 0.808 |
| 87 | 142.5 | 83 | 47 | 284 | 0.500 | 0.52 | 0.92 | 0.2423 | 4.13 | 0.852 |
| 82 | 0 | 82 | 46 | 284 | 0.000 | 0.17 | 0.92 | #DIV/0! | #DIV/0! | #DIV/0! |
| 77 | 0 | 81 | 45 | 284 | 0.000 | 0.17 | 0.92 | #DIV/0! | #DIV/0! | #DIV/0! |
| 72 | 285 | 80 | 44 | 283 | 1.000 | 1.00 | 0.93 | 0.2311 | 4.33 | 0.813 |
| 67 | 143 | 79 | 43 | 282 | 0.500 | 0.52 | 0.93 | 0.2436 | 4.10 | 0.857 |
| 62 | 114 | 78 | 42 | 281 | 0.400 | 0.44 | 0.93 | 0.2583 | 3.87 | 0.908 |
| 57 | 86 | 77 | 41 | 279 | 0.300 | 0.37 | 0.93 | 0.2862 | 3.49 | 1.006 |
| 52 | 57 | 76 | 40 | 277 | 0.200 | 0.30 | 0.93 | 0.3475 | 2.88 | 1:222 |
| 47 | 29 | 75 | 39 | 275 | 0.100 | 0.23 | 0.93 | 0.5419 | 1.85 | 1.905 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2771: Baseline Chiller #2, Other Months

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.73 |
| Nom. Tons | 511 |
| nom kw | 373.03 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 97 | 511 | 85 | 49 | 509 | 1.000 | 1.00 | 0.92 | 0.1902 | 5.26 | 0.669 |
| 92 | 511 | 84 | 48 | 509 | 1.000 | 1.00 | 0.92 | 0.1906 | 5.25 | 0.670 |
| 87 | 511 | 83 | 47 | 510 | 1.000 | 1.00 | 0.92 | 0.1909 | 5.24 | 0.671 |
| 82 | 383 | 82 | 46 | 509 | 0.750 | 0.75 | 0.92 | 0.1908 | 5.24 | 0.671 |
| 77 | 256 | 81 | 45 | 509 | 0.500 | 0.52 | 0.92 | 0.2016 | 4.96 | 0.709 |
| 72 | 127.75 | 80 | 44 | 508 | 0.250 | 0.33 | 0.93 | 0.2564 | 3.90 | 0.901 |
| 67 | 0 | 79 | 43 | 506 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 62 | 0 | 78 | 42 | 503 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 57 | 0 | 77 | 41 | 501 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 52 | 0 | 76 | 40 | 497 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 47 | 0 | 75 | 39 | 494 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2771: Post-Retrofit Chiller #1, Summer Months

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | | | |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.88 |
| Nom. Tons | 285 |
| nom kw | 250.8 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 97 | 285 | 85 | 49 | 284 | 1.000 | 1.00 | 0.92 | 0.2293 | 4.36 | 0.806 |
| 92 | 285 | 84 | 48 | 284 | 1.000 | 1.00 | 0.92 | 0.2297 | 4.35 | 0.808 |
| 87 | 142.5 | 83 | 47 | 284 | 0.500 | 0.52 | 0.92 | 0.2423 | 4.13 | 0.852 |
| 82 | 0 | 82 | 46 | 284 | 0.000 | 0.17 | 0.92 | #DIV/0! | #DIV/0! | #DIV/0! |
| 77 | 0 | 81 | 45 | 284 | 0.000 | 0.17 | 0.92 | #DIV/0! | #DIV/0! | #DIV/0! |
| 72 | 0 | 80 | 44 | 283 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 67 | 0 | 79 | 43 | 282 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 62 | 0 | 78 | 42 | 281 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 57 | 0 | 77 | 41 | 279 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 52 | 0 | 76 | 40 | 277 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 47 | 0 | 75 | 39 | 275 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | | | |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2771: Post-Retrofit Chiller #2, Summer Months

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.73 |
| Nom. Tons | 511 |
| nom kw | 373.03 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 97 | 511 | 85 | 49 | 509 | 1.000 | 1.00 | 0.92 | 0.1902 | 5.26 | 0.669 |
| 92 | 511 | 84 | 48 | 509 | 1.000 | 1.00 | 0.92 | 0.1906 | 5.25 | 0.670 |
| 87 | 511 | 83 | 47 | 510 | 1.000 | 1.00 | 0.92 | 0.1909 | 5.24 | 0.671 |
| 82 | 511 | 82 | 46 | 509 | 1.000 | 1.00 | 0.92 | 0.1912 | 5.23 | 0.672 |
| 77 | 409 | 81 | 45 | 509 | 0.800 | 0.79 | 0.92 | 0.1906 | 5.25 | 0.670 |
| 72 | 306.6 | 80 | 44 | 508 | 0.600 | 0.61 | 0.93 | 0.1954 | 5.12 | 0.687 |
| 67 | 204.4 | 79 | 43 | 506 | 0.400 | 0.44 | 0.93 | 0.2140 | 4.67 | 0.753 |
| 62 | 0 | 78 | 42 | 503 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 57 | 0 | 77 | 41 | 501 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 52 | 0 | 76 | 40 | 497 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 47 | 0 | 75 | 39 | 494 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2771: Baseline Chiller #1, Summer Months

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.88 |
| Nom. Tons | 285 |
| nom kw | 250.8 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 97 | 285 | 85 | 49 | 284 | 1.000 | 1.00 | 0.92 | 0.2293 | 4.36 | 0.806 |
| 92 | 285 | 84 | 48 | 284 | 1.000 | 1.00 | 0.92 | 0.2297 | 4.35 | 0.808 |
| 87 | 142.5 | 83 | 47 | 284 | 0.500 | 0.52 | 0.92 | 0.2423 | 4.13 | 0.852 |
| 82 | 0 | 82 | 46 | 284 | 0.000 | 0.17 | 0.92 | #DIV/0! | #DIV/0! | #DIV/0! |
| 77 | 0 | 81 | 45 | 284 | 0.000 | 0.17 | 0.92 | #DIV/0! | #DIV/0! | #DIV/0! |
| 72 | 0 | 80 | 44 | 283 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 67 | 0 | 79 | 43 | 282 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 62 | 0 | 78 | 42 | 281 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 57 | 0 | 77 | 41 | 279 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 52 | 0 | 76 | 40 | 277 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |
| 47 | 0 | 75 | 39 | 275 | 0.000 | 0.17 | 0.93 | #DIV/0! | #DIV/0! | #DIV/0! |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2771: Baseline Chiller #2, Summer Months

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.73 |
| Nom. Tons | 511 |
| nom kw | 373.03 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 97 | 511 | 85 | 49 | 509 | 1.000 | 1.00 | 0.92 | 0.1902 | 5.26 | 0.669 |
| 92 | 511 | 84 | 48 | 509 | 1.000 | 1.00 | 0.92 | 0.1906 | 5.25 | 0.670 |
| 87 | 511 | 83 | 47 | 510 | 1.000 | 1.00 | 0.92 | 0.1909 | 5.24 | 0.671 |
| 82 | 511 | 82 | 46 | 509 | 1.000 | 1.00 | 0.92 | 0.1912 | 5.23 | 0.672 |
| 77 | 409 | 81 | 45 | 509 | 0.800 | 0.79 | 0.92 | 0.1906 | 5.25 | 0.670 |
| 72 | 357.7 | 80 | 44 | 508 | 0.700 | 0.70 | 0.93 | 0.1921 | 5.20 | 0.676 |
| 67 | 306.6 | 79 | 43 | 506 | 0.600 | 0.61 | 0.93 | 0.1957 | 5.11 | 0.688 |
| 62 | 255.5 | 78 | 42 | 503 | 0.500 | 0.52 | 0.93 | 0.2023 | 4.94 | 0.711 |
| 57 | 204.4 | 77 | 41 | 501 | 0.400 | 0.44 | 0.93 | 0.2145 | 4.66 | 0.754 |
| 52 | 153.3 | 76 | 40 | 497 | 0.300 | 0.37 | 0.93 | 0.2377 | 4.21 | 0.836 |
| 47 | 102.2 | 75 | 39 | 494 | 0.200 | 0.30 | 0.93 | 0.2885 | 3.47 | 1.014 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2771: Other Months Weather Data

TMY temperature data

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 32 | 0 | 0 | 1 | 4 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 37 | 6 | 9 | 13 | 13 | 16 | 15 | 18 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 6 | |
| 42 | 28 | 31 | 34 | 46 | 45 | 44 | 38 | 28 | 12 | 5 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 5 | 6 | 7 | 16 | 21 | 26 | |
| 47 | 72 | 77 | 79 | 83 | 71 | 65 | 70 | 65 | 43 | 31 | 12 | 8 | 6 | 3 | 2 | 2 | 2 | 6 | 21 | 32 | 44 | 43 | 48 | 54 | 250 |
| 52 | 101 | 100 | 99 | 82 | 96 | 98 | 86 | 83 | 79 | 68 | 60 | 43 | 26 | 20 | 17 | 21 | 36 | 53 | 68 | 77 | 91 | 102 | 114 | 115 | 592 |
| 57 | 57 | 50 | 43 | 39 | 38 | 45 | 50 | 74 | 88 | 83 | 83 | 79 | 68 | 70 | 80 | 79 | 95 | 107 | 102 | 103 | 93 | 86 | 67 | 61 | 956 |
| 62 | 8 | 6 | 4 | 6 | 6 | 6 | 9 | 18 | 38 | 60 | 70 | 67 | 71 | 80 | 74 | 78 | 77 | 69 | 54 | 46 | 35 | 21 | 16 | 10 | 711 |
| 67 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 9 | 19 | 31 | 42 | 51 | 53 | 55 | 46 | 36 | 23 | 18 | 7 | 3 | 2 | 2 | 1 | 368 |
| 72 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 4 | 11 | 22 | 30 | 26 | 26 | 25 | 14 | 10 | 5 | 2 | 0 | 0 | 0 | 0 | 172 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 9 | 13 | 11 | 9 | 10 | 8 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 71 |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 5 | 6 | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 29 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 4 | 3 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 102 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 107 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 112 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| On Hours for Heat Exchanger | | | | | | | 215 | 240 | 248 | 242 | 225 | 197 | 171 | 173 | 173 | 180 | 210 | 235 | | | | | | | 1284.29 |
| On Hours for Chiller | | | | | | | 1 | 3 | 12 | 26 | 47 | 76 | 102 | 99 | 99 | 92 | 62 | 36 | | | | | | | 975.71 |

Note: Total "On Hours" value has been scaled by 5/7 to account for M-F operation only

Actual temperature data for climate zone 13 for 1/1/98 to 12/31/98

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 32 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | |
| 37 | 6 | 8 | 7 | 8 | 10 | 9 | 13 | 10 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 3 | 2 | 1 | |
| 42 | 21 | 24 | 29 | 32 | 33 | 33 | 28 | 17 | 8 | 8 | 4 | 1 | 1 | 0 | 0 | 0 | 1 | 3 | 3 | 4 | 6 | 10 | 16 | 19 | |
| 47 | 45 | 45 | 45 | 43 | 44 | 43 | 40 | 42 | 38 | 24 | 16 | 12 | 9 | 10 | 7 | 6 | 8 | 13 | 18 | 28 | 37 | 37 | 39 | 44 | 225 |
| 52 | 76 | 76 | 72 | 74 | 74 | 72 | 59 | 54 | 54 | 50 | 43 | 37 | 25 | 23 | 24 | 30 | 39 | 52 | 66 | 71 | 73 | 80 | 76 | 75 | 490 |
| 57 | 32 | 28 | 30 | 26 | 23 | 24 | 38 | 46 | 51 | 57 | 59 | 52 | 56 | 58 | 62 | 61 | 67 | 70 | 70 | 61 | 53 | 45 | 41 | 33 | 677 |
| 62 | 11 | 10 | 7 | 7 | 5 | 8 | 8 | 15 | 23 | 34 | 38 | 51 | 53 | 48 | 52 | 55 | 42 | 33 | 19 | 12 | 12 | 9 | 15 | 16 | 452 |
| 67 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 10 | 9 | 19 | 23 | 30 | 32 | 26 | 22 | 19 | 7 | 5 | 11 | 7 | 7 | 1 | 0 | 202 |
| 72 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 5 | 4 | 5 | 5 | 8 | 7 | 4 | 3 | 6 | 9 | 2 | 0 | 0 | 0 | 0 | 52 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 6 | 7 | 4 | 1 | 2 | 3 | 7 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 42 |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 6 | 9 | 10 | 10 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 45 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 102 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 107 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 112 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| On Hours for Heat Exchanger | | | | | | | 145 | 157 | 166 | 165 | 156 | 152 | 143 | 139 | 145 | 152 | 156 | 168 | | | | | | | 1844.00 |
| On Hours for Chiller | | | | | | | 3 | 5 | 14 | 18 | 31 | 38 | 47 | 52 | 46 | 39 | 34 | 20 | | | | | | | 347.00 |

Site 2771: Summer Months Weather Data

TMY temperature data

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 42 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 47 | 0 | 0 | 0 | 1 | 0 | 1 | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 52 | 19 | 25 | 26 | 34 | 31 | 24 | **18** | **2** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 1 | 2 | 5 | 10 | 12 | 20 |
| 57 | 59 | 55 | 57 | 51 | 57 | 61 | **62** | **46** | **16** | **6** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **1** | 13 | 26 | 36 | 51 | 60 | 64 | 131 |
| 62 | 13 | 11 | 8 | 5 | 3 | 5 | **10** | **40** | **60** | **42** | **21** | **10** | **6** | **3** | **5** | **6** | **14** | **42** | 55 | 53 | 48 | 34 | 19 | 15 | 259 |
| 67 | 1 | 0 | 1 | 1 | 1 | 1 | **2** | **3** | **11** | **37** | **43** | **35** | **21** | **25** | **29** | **32** | **47** | **37** | 20 | 12 | 6 | 2 | 3 | 1 | 322 |
| 72 | 0 | 1 | 0 | 0 | 0 | 0 | **0** | **1** | **4** | **5** | **21** | **29** | **34** | **35** | **32** | **32** | **23** | **9** | 4 | 0 | 0 | 0 | 0 | 0 | 225 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **1** | **2** | **5** | **12** | **18** | **19** | **19** | **18** | **7** | **3** | 0 | 0 | 0 | 0 | 0 | 0 | 104 |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | **0** | **2** | **5** | **8** | **6** | **5** | **3** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 29 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | **0** | **0** | **1** | **5** | **3** | **2** | **1** | **1** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 13 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **1** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 102 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 107 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 112 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| On Hours for Heat Exchanger | | | | | | | 90 | 88 | 76 | 48 | 21 | 10 | 6 | 3 | 5 | 6 | 14 | 43 | | | | | | | **107.86** |
| On Hours for Chiller | | | | | | | 2 | 4 | 16 | 44 | 71 | 82 | 86 | 89 | 87 | 86 | 78 | 49 | | | | | | | **680.71** |

Note: Total "On Hours" value has been scaled by 5/7 to account for M-F operation only

Actual temperature data for climate zone 13 for 1/1/98 to 12/31/98

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 42 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 47 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 52 | 1 | 1 | 2 | 1 | 2 | 1 | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 1 | 0 | 2 | 2 | 0 |
| 57 | 38 | 43 | 47 | 47 | 48 | 50 | **41** | **26** | **16** | 7 | **3** | **3** | **0** | **0** | **0** | **0** | **0** | **2** | 8 | 19 | 24 | 31 | 34 | 34 | 98 |
| 62 | 22 | 18 | 13 | 14 | 12 | 12 | **21** | **29** | **31** | **28** | **24** | **16** | **16** | **11** | 12 | **17** | **22** | **30** | 42 | 36 | 34 | 30 | 25 | 25 | 257 |
| 67 | 4 | 3 | 3 | 3 | 3 | 2 | 1 | **8** | **11** | **17** | **20** | **21** | **20** | **23** | **24** | **24** | **23** | **20** | 11 | 6 | 2 | 2 | 3 | 3 | 212 |
| 72 | 0 | 0 | 0 | 0 | 0 | 0 | **2** | 1 | **5** | **12** | **11** | **15** | **16** | **17** | **14** | **12** | **11** | **9** | 2 | 3 | 4 | 2 | 1 | 1 | 125 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **1** | **2** | **0** | **6** | **7** | **7** | **8** | **9** | **7** | **6** | **2** | 1 | 1 | 0 | 0 | 0 | 0 | 55 |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | 1 | **0** | **2** | **5** | **3** | **3** | **3** | **1** | **2** | 1 | 0 | 0 | 0 | 0 | 0 | 20 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | **0** | **1** | **1** | **0** | **3** | **3** | **2** | **2** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | **0** | **0** | **0** | **1** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 102 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 107 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 112 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| On Hours for Heat Exchanger | | | | | | | 62 | 55 | 47 | 35 | 27 | 19 | 16 | 11 | 12 | 17 | 22 | 32 | | | | | | | **355.00** |
| On Hours for Chiller | | | | | | | 3 | 10 | 18 | 30 | 38 | 46 | 49 | 54 | 53 | 48 | 43 | 33 | | | | | | | **425.00** |

**Chiller Installation (Site 2773)**

| | |
|---|---|
| Program | Advance Performance Options Program |
| Measure | High Efficiency Water-Cooled Chiller |
| Site Description | Office |

**Measure Description**

Install a new 550-ton water-cooled chiller to operate as the primary chiller. This provides staging with two existing 1350 ton chillers.

**Summary of Ex Ante Impact Calculations**

Impacts were developed using DOE2.1E simulation program based on climate zone, building type, and chiller characteristics.

**Comments on Calculations**

The correct climate zone, chiller size category and building characteristics were used in the application calculations. However, the impact calculations were based on the pre-retrofit conditions as opposed to the baseline Title 24 conditions, resulting in a considerable over-estimation of impact. In addition, the demand impact estimate was based on the minimum summer demand savings instead of the peak hour demand impact, resulting in a very large under-estimation of the demand impact.

**Evaluation Process**

The evaluation process consists of a review of the application form and supporting documentation, conducting an on-site survey and then computing impacts using the on-site data.

The on-site survey was conducted on July 27, 1999 in San Francisco (Climate Zone 3). Information on the retrofit equipment and operating conditions were collected through an inspection of the chiller and through an interview with the Chief Engineer.

Discussions provided data for development of a relationship between chiller loading and outdoor dry bulb. The chiller is available from 6:00 am to 6:00 pm every day. The chiller is generally brought on line at 62 degrees F outside air temperature. The Chief Engineer estimated that the chiller reaches 100% loading at approximately 90 degrees F outside air temperature. The secondary chiller operates only three to four days per year.

Models are calibrated with actual weather, the chiller lock-out temperature, chiller loading under extreme outdoor temperature conditions, chilled water temperature, and condenser water temperature. Energy impacts are based on typical weather data. A Title 24 baseline, nominal efficiency, and typical year bin weather data for the applicable climate zone are used in the bin analysis. To compute the impacts, the following assumptions were used:

- A linear loading strategy was used for the analysis of both the baseline and rebated chillers, which assumed initial loading at 62 degrees F and 100% loading at 89 Degrees F. Full loading was adjusted to 89 degrees to accommodate for the secondary chiller operating three to four days per year.

- Based on a water-cooled chiller greater than 300 tons, a baseline Title 24 efficiency of 0.748 KW/ton was used.

Chiller efficiencies at various temperatures were calculated from updated default performance coefficients provided in a memo to the California Energy Commission titled "1995 Proposed Changes to the ACM Manual Central Plant Cooling Equipment" by Mark Hydeman. These coefficients were used to develop a chiller efficiency curve for the Rebate case and a Title 24 base case. Evaluation-based demand impacts were higher and energy impacts were lower than ex ante estimates. Results from these calculations are summarized below and documented in the attached workbook.

**Additional Notes**

The site has installed a plate & frame heat exchanger since the retrofit, making it impossible to calibrate the model to weather data using chiller run hours. Due to the quality of information supplied by the contact, the ex post model is assumed to be accurate.

**Impact Results**

| | KW | KWh | Therm |
|---|---|---|---|
| **MDSS** | 22 | 474,024.84 | 0 |
| **Adjusted Engineering** | 179.91 | 103,700.41 | 0 |
| **Engineering Realization Rate** | 8.18 | 0.22 | N/A |

Site 2773: Results

| | Impacts | | Savings | |
|---|---|---|---|---|
| | Energy | Demand | Energy | Demand |
| MDSS | 474,025 | 22 | | |
| QC | 103,700 | 180 | 275,812 | 175 |
| Realization Rate | 0.22 | 8.18 | 0.58 | 7.93 |

| Post-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.341 |
| Nom. Tons | 550 |
| nom kw | 187.55 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 87 | 20 | 550 | 0.274 | 3,014.13 | 150.71 | 54.00 | 8,138.16 |
| 82 | 41 | 454 | 0.273 | 5,124.27 | 123.69 | 114.00 | 14,100.57 |
| 77 | 125 | 358 | 0.272 | 12,175.93 | 97.41 | 170.00 | 16,559.27 |
| 72 | 284 | 261 | 0.279 | 20,675.76 | 72.91 | 264.00 | 19,248.76 |
| 67 | 493 | 165 | 0.300 | 24,416.60 | 49.54 | 542.00 | 26,851.18 |
| 62 | 693 | 69 | 0.451 | 21,459.28 | 30.97 | 954.00 | 29,547.44 |
| Totals | 1,656 | | | 86,865.97 | 150.71 | 2,098.00 | 114,445.38 |

| Title 24 Baseline Chiller | |
|---|---|
| Nom. Eff | 0.748 |
| Nom. Tons | 550 |
| nom kw | 411.447 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year) | Peak Demand (kW) |
|---|---|---|---|---|---|
| 87 | 20 | 550 | 0.601 | 6,612.40 | 330.62 |
| 82 | 41 | 454 | 0.598 | 11,241.61 | 271.35 |
| 77 | 125 | 358 | 0.598 | 26,711.54 | 213.69 |
| 72 | 284 | 261 | 0.612 | 45,358.43 | 159.95 |
| 67 | 493 | 165 | 0.659 | 53,565.08 | 108.68 |
| 62 | 693 | 69 | 0.988 | 47,077.33 | 67.95 |
| Totals | 1,656 | | | 190,566.38 | 330.62 |

| Pre-Retrofit Chiller | |
|---|---|
| Nom. Eff | 0.707 |
| Nom. Tons | 1350 |
| nom kw | 954.45 |

| Outdoor DB Temperature (F) | Operating Hours per year (TMY) | Tons Output | Efficiency (kW/Ton) | Annual Energy Use (kWh/year), (TMY) | Peak Demand (kW) | Operating Hours per year (Actual) | Annual Energy Use (kWh/year), (Actual) |
|---|---|---|---|---|---|---|---|
| 87 | 20 | 550 | 0.591 | 6,505.39 | 325.27 | 54.00 | 17,564.56 |
| 82 | 41 | 454 | 0.630 | 11,844.76 | 285.91 | 114.00 | 32,593.50 |
| 77 | 125 | 358 | 0.684 | 30,583.90 | 244.67 | 170.00 | 41,594.11 |
| 72 | 284 | 261 | 0.790 | 58,491.92 | 206.27 | 264.00 | 54,454.95 |
| 67 | 493 | 135 | 1.208 | 80,402.26 | 163.14 | 542.00 | 88,419.18 |
| 62 | 693 | 135 | 1.208 | 113,029.27 | 163.14 | 954.00 | 155,630.82 |
| Totals | 1,656 | | | 300,857.51 | 325.27 | 2,098.00 | 390,257.12 |

Site 2773: Inputs to Model

| Parameter | Value Reported | Units of Parameter | Notes |
|---|---|---|---|
| Building Location | San Francisco | | |
| Climate Zone | 3 | | |
| | | | |
| Chiller 1: 2 Compressors at 275-tons Each | | | Application |
| Post-Retrofit Chiller Nominal Capacity | 550 | Tons | Application |
| Post-Retrofit Chiller Nominal Efficiency | 0.341 | kW/ton | From Chiller Rating Sheet |
| Post-Retrofit Chiller Startup OSA Temperature | 62 | F | Contact provided estimate |
| Post-Retrofit Chilller Max Load OSA Temperature | 90 | F | Contact provided estimate |
| Post-Retrofit Chiller Chilled Water Supply Temperature Setpoint | 48 | F | Contact provided setpoints |
| Post-Retrofit Chiller Condenser Water Temperature Setpoint | 74 | F | Contact provided setpoints |
| | | | |
| Pre-Retrofit Chiller Nominal Capacity | 1350 | Tons | Application |
| Pre-Retrofit Chiller Nominal Efficiency | 0.707 | kW/ton | Application |
| | | | |
| Baseline Chiller Efficiency | 0.748 | kW/ton | Title 24 Nominal Efficiency for Chiller > 300 Tons |
| | | | |
| Chiller AM Lockout | 6:00 | AM | 24 hours per day, 7 days per week |
| Chiller PM Lockout | 6:00 | PM | 24 hours per day, 7 days per week |
| Post-Retrofit Compressor #1 Run Hours | 689 | hours | Documented from Chiller Log |
| Post-Retrofit Compressor #2 Run Hours | 609 | hours | Documented from Chiller Log |
| Total Post-Retrofit Chiller Run Hours | 689 | hours | = Compressor #1 Run Hours + Compressor #2 Run Hours |
| Date of Chiller Installation | 8/31/98 | | Contact provided estimate |
| Date at Run Hour Reading | 11/4/99 | | |
| Number of Days Chillers Operated | 431 | days | = ((Read Date - Install Date) * 5/7) - 10 Holidays |
| Average Hours per Year of Operation for Post-retrofit Chiller | 583.49 | Hours/Year | = (Run Hours for New Compressor / Number of Days Compressor Operated) * 365 Days/Year |
| Total Modeled Post-Retrofit Compressor Run Hours | 1738.00 | hours | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |
| Total Modeled Post-Retrofit Hours per Year | 2098.00 | Hours/Year | Based on setpoints and actual weather data; See Weather Data Spreadsheet for Details |

Site 2773: Post-Retrofit Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.341 |
| Nom. Tons | 550 |
| nom kw | 187.55 |

| Outdoor DB Temperature | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 87 | 550 | 75 | 48 | 569 | 1.000 | 1.00 | 0.81 | 0.0779 | 12.83 | 0.274 |
| 82 | 454 | 75 | 48 | 569 | 0.825 | 0.82 | 0.81 | 0.0775 | 12.90 | 0.273 |
| 77 | 358 | 74 | 48 | 569 | 0.650 | 0.65 | 0.79 | 0.0775 | 12.90 | 0.272 |
| 72 | 261 | 72 | 48 | 569 | 0.475 | 0.50 | 0.77 | 0.0794 | 12.60 | 0.279 |
| 67 | 165 | 67 | 48 | 563 | 0.300 | 0.37 | 0.72 | 0.0854 | 11.71 | 0.300 |
| 62 | 69 | 62 | 48 | 548 | 0.125 | 0.25 | 0.66 | 0.1281 | 7.80 | 0.451 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2773: Baseline Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.74808511 |
| Nom. Tons | 550 |
| nom kw | 411.446809 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 87 | 550 | 75 | 48 | 569 | 1.000 | 1.00 | 0.81 | 0.1710 | 5.85 | 0.601 |
| 82 | 454 | 75 | 48 | 569 | 0.825 | 0.82 | 0.81 | 0.1701 | 5.88 | 0.598 |
| 77 | 358 | 74 | 48 | 569 | 0.650 | 0.65 | 0.79 | 0.1700 | 5.88 | 0.598 |
| 72 | 261 | 72 | 48 | 569 | 0.475 | 0.50 | 0.77 | 0.1741 | 5.74 | 0.612 |
| 67 | 165 | 67 | 48 | 563 | 0.300 | 0.37 | 0.72 | 0.1873 | 5.34 | 0.659 |
| 62 | 69 | 62 | 48 | 548 | 0.125 | 0.25 | 0.66 | 0.2811 | 3.56 | 0.988 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2773: Pre-Retrofit Chiller

| Centrifugal Chiller (Water-Source) | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Capacity Correction (Tout, Tin) | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| Part Load Efficiency (PLR) | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |
| Temp Efficiency (Tout, Tin) | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |

| | |
|---|---|
| Nom. Eff | 0.707 |
| Nom. Tons | 1350 |
| nom kw | 954.45 |

| | Current Data | | | Calculated Values | | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor DB Temperature | Tons Output | Condenser Temp | Supply temp | Current Capacity | Part Load Ratio | Part Load Adjustment to EIR | Ambient Adjustment to EIR | EIR | COP | kW/Ton |
| 87 | 550 | 64 | 42 | 1376 | 0.407 | 0.45 | 0.76 | 0.1682 | 5.95 | 0.591 |
| 82 | 454 | 64 | 42 | 1376 | 0.336 | 0.40 | 0.76 | 0.1792 | 5.58 | 0.630 |
| 77 | 358 | 63 | 42 | 1373 | 0.265 | 0.34 | 0.75 | 0.1947 | 5.14 | 0.684 |
| 72 | 261 | 62 | 42 | 1368 | 0.194 | 0.29 | 0.73 | 0.2246 | 4.45 | 0.790 |
| 67 | 135 | 62 | 42 | 1368 | 0.100 | 0.23 | 0.73 | 0.3437 | 2.91 | 1.208 |
| 62 | 135 | 62 | 42 | 1368 | 0.100 | 0.23 | 0.73 | 0.3437 | 2.91 | 1.208 |

EIR = EIRrated x EIR-FT x EIR-FPLR / PLR.

Chiller Plant Coefficients -- Electric Water-Cooled Chillers (source Mark Hydeman October 2, 1997 Proposed Changes to the ACM Manual -- Central Plant Cooling Equipment)

| Curve | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| CAPFT | -0.29861976 | 0.02996076 | -0.00080125 | 0.01736268 | -0.00032606 | 0.00063139 |
| EIRFT | 0.51777196 | -0.00400363 | 0.00002028 | 0.00698793 | 0.00008290 | -0.00015467 |
| EIRFPLR | 0.17149273 | 0.58820208 | 0.23737257 | - | - | - |

CAP-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in capacity as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water supply temperature (CWS, or Tin).

EIR-FPLR = A + (B x PLR) + (C x PLR x PLR)
This describes the change in EIR as a function of part load conditions (PLR, the part load ratio).

EIR-FT = A + (B x CHWS) + (C x CHWS x CHWS) + (D x CWS) + (E x CWS x CWS) + (F x CHWS x CWS)
This describes the change in EIR as a function of the chilled water supply temperature (CHWS, or Tout) and condenser water (CWS, or Tin) temperatures.

souce of equations: ASHRAE/IES Standard 90.1-1989 User's Manual - November 1992.

Site 2773: Weather Data

TMY temperature data

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 0 | 0 | 1 | 4 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 37 | 6 | 9 | 13 | 13 | 16 | 15 | 18 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 6 | |
| 42 | 28 | 31 | 34 | 46 | 45 | 44 | 38 | 28 | 12 | 5 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 5 | 6 | 7 | 16 | 21 | 26 | |
| 47 | 72 | 77 | 79 | 84 | 71 | 66 | 70 | 65 | 43 | 31 | 12 | 8 | 6 | 3 | 2 | 2 | 2 | 6 | 21 | 32 | 44 | 43 | 48 | 54 | |
| 52 | 120 | 125 | 125 | 116 | 127 | 122 | 104 | 85 | 79 | 68 | 60 | 43 | 26 | 20 | 17 | 21 | 36 | 53 | 68 | 78 | 93 | 107 | 124 | 127 | |
| 57 | 116 | 105 | 100 | 90 | 95 | 106 | 112 | 120 | 104 | 89 | 83 | 79 | 68 | 70 | 80 | 79 | 95 | 108 | 115 | 129 | 129 | 137 | 127 | 125 | |
| 62 | 21 | 17 | 12 | 11 | 9 | 11 | 19 | 58 | 98 | 102 | 91 | 77 | 77 | 83 | 79 | 84 | 91 | 111 | 109 | 99 | 83 | 55 | 35 | 25 | 693 |
| 67 | 2 | 0 | 1 | 1 | 1 | 1 | 3 | 5 | 20 | 56 | 74 | 77 | 72 | 78 | 84 | 78 | 83 | 60 | 38 | 19 | 9 | 4 | 5 | 2 | 493 |
| 72 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 9 | 32 | 51 | 64 | 61 | 58 | 57 | 37 | 19 | 9 | 2 | 0 | 0 | 0 | 0 | 284 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 10 | 21 | 31 | 30 | 28 | 28 | 15 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 125 |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 8 | 13 | 11 | 11 | 9 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 41 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 7 | 5 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| On Hours for Chiller | | | | | | | 22 | 65 | 126 | 172 | 209 | 235 | 265 | 270 | 265 | 262 | 231 | 196 | | | | | | | 1655.71 |

Note: Total "On Hours" value has been scaled by 5/7 to account for M-F operation only

Actual temperature by hour from 07/28/98 to 07/27/99

| Temp | 0:00 | 1:00 | 2:00 | 3:00 | 4:00 | 5:00 | 6:00 | 7:00 | 8:00 | 9:00 | 10:00 | 11:00 | 12:00 | 13:00 | 14:00 | 15:00 | 16:00 | 17:00 | 18:00 | 19:00 | 20:00 | 21:00 | 22:00 | 23:00 | On Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 1 | 1 | 2 | 2 | 4 | 4 | 4 | 4 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 3 | |
| 37 | 9 | 12 | 11 | 12 | 13 | 13 | 16 | 14 | 5 | . | . | . | . | . | . | . | . | . | 1 | 2 | 4 | 3 | 6 | 5 | |
| 42 | 27 | 32 | 37 | 43 | 47 | 46 | 43 | 26 | 17 | 12 | 7 | 2 | 2 | . | 1 | 1 | 3 | 5 | 7 | 9 | 13 | 20 | 23 | 26 | |
| 47 | 66 | 68 | 70 | 66 | 68 | 63 | 55 | 56 | 50 | 33 | 23 | 18 | 12 | 13 | 10 | 10 | 14 | 25 | 35 | 45 | 52 | 51 | 54 | 57 | |
| 52 | 110 | 111 | 106 | 111 | 108 | 109 | 92 | 80 | 75 | 75 | 63 | 52 | 40 | 38 | 37 | 46 | 59 | 75 | 85 | 94 | 100 | 108 | 107 | 109 | |
| 57 | 97 | 94 | 102 | 96 | 94 | 97 | 101 | 103 | 94 | 86 | 80 | 78 | 79 | 81 | 86 | 84 | 91 | 94 | 114 | 118 | 117 | 114 | 107 | 100 | |
| 62 | 47 | 42 | 32 | 30 | 26 | 28 | 39 | 47 | 70 | 84 | 86 | 88 | 92 | 80 | 91 | 101 | 89 | 87 | 73 | 59 | 55 | 49 | 55 | 55 | 954 |
| 67 | 5 | 3 | 4 | 5 | 5 | 5 | 10 | 25 | 30 | 37 | 55 | 59 | 60 | 69 | 60 | 53 | 51 | 33 | 26 | 22 | 16 | 15 | 9 | 8 | 542 |
| 72 | 3 | 2 | 1 | . | . | . | 5 | 8 | 16 | 22 | 21 | 30 | 34 | 32 | 25 | 24 | 23 | 24 | 15 | 12 | 7 | 5 | 3 | 2 | 264 |
| 77 | . | . | . | . | . | . | . | 2 | 6 | 10 | 19 | 20 | 19 | 21 | 24 | 18 | 16 | 15 | 6 | 4 | 1 | . | . | . | 170 |
| 82 | . | . | . | . | . | . | . | . | 2 | 6 | 9 | 11 | 13 | 17 | 19 | 18 | 15 | 4 | 3 | . | . | . | . | . | 114 |
| 87 | . | . | . | . | . | . | . | . | . | . | 2 | 7 | 11 | 11 | 9 | 8 | 3 | 3 | . | . | . | . | . | . | 54 |
| 92 | . | . | . | . | . | . | . | . | . | . | . | . | 2 | 2 | 2 | 1 | 1 | . | . | . | . | . | . | . | |
| 97 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | 1 | . | . | . | . | . | . | . | . | |
| On Hours for Chiller | | | | | | | 54 | 82 | 124 | 159 | 192 | 215 | 229 | 230 | 228 | 222 | 197 | 166 | | | | | | | 2098.00 |

*Attachment 2*

*Standard HVAC Algorithm Review*

## 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. |

**Setback Programmable Thermostat:**

**1) Installs setback programmable thermostats in spaces with regular occupied and unoccupied periods.**

**2) Assumptions used in Advice Filing:**

Office hours = 07:00-18:00 M-F
Occupied Hours = 11 hr/day x 5 day/week x 52.14 week/yr
= 2,868
= Listed as 2,870 hr/year
AC size = 10 tons (120,000 Btu)
AC Efficiency = 1.3 kW/ton with out fans
EER = 9.23 Btu/Watt (calculated in spreadsheet "Window Film AF")
Area serviced/ton = 500 sqft/ton
Heating size = 250 kBtu/hr
Heating efficiency = 70%
Area served = 50 Btu/hr-sqft
Total cfm = 5,000
Fan hp = 3
Outside Supply Air = 20%
Location = San Jose, ASHRAE bin weather data

- **A bin analysis method is used, where:**

OSA = outside air temp (F)
Bin = hours per year that temp is in a given range (hr/yr)
% OSA = percent outside air (fixed at 20%)
Ret Air = return air temp (F)
Mix Air = mixed air temperature
= (% OSA x OSA) + [(1 - % OSA) x Ret Air]
67 F = temp at which system switches from cooling to heating
SAT = supply air temp (F)
SAT (cooling) = 67 F + {[67 F - OSA)/5] x 2}
SAT (heating) = 67 F + {[67 F - OSA)/5] x 3}
Heating Loads (kBtu/yr) = [SAT - Mix Air (F)] x Bin (hr/yr) x (1.085 Btu/hr-F-CFM) x Air Flow (CFM)
Cooling Loads (kBtu/yr) = [Mix Air - SAT (F)] x Bin (hr/yr) x (1.085 Btu/hr-F-CFM) x Air Flow (CFM)

**Sample Heating and Cooling Load Calculations for San Jose**

| Outside Air (F) | Total Bin (hr/yr) | % OSA | Return Air (F) | Mixed Air (F) | Supply Air (F) | Cooling (kBtu/yr) | Heating (kBtu/yr) |
|---|---|---|---|---|---|---|---|
| 92 | 6 | 20% | 74 | 77.6 | 57 | 671 | 0 |
| 87 | 24 | 20% | 74 | 76.6 | 59 | 2,292 | 0 |
| 82 | 84 | 20% | 74 | 75.6 | 61 | 6,653 | 0 |
| 77 | 207 | 20% | 74 | 74.6 | 63 | 13,027 | 0 |
| 72 | 535 | 20% | 74 | 73.6 | 65 | 24,960 | 0 |
| 67 | 1,077 | 20% | 74 | 72.6 | 67 | 32,719 | 0 |
| 62 | 1,756 | 20% | 74 | 71.6 | 70 | 15,242 | 0 |
| 57 | 1,977 | 20% | 74 | 70.6 | 73 | 0 | 25,741 |
| 52 | 1,545 | 20% | 74 | 69.6 | 76 | 0 | 53,642 |
| 47 | 935 | 20% | 74 | 68.6 | 79 | 0 | 52,753 |
| 42 | 451 | 20% | 74 | 67.6 | 82 | 0 | 35,232 |
| 37 | 138 | 20% | 74 | 66.6 | 85 | 0 | 13,775 |
| 32 | 24 | 20% | 74 | 65.6 | 88 | 0 | 2,916 |
| 27 | 1 | 20% | 74 | 64.6 | 91 | 0 | 143 |
| Total | 8,760 | | | | Total | 95,584 | 184,203 |

Recreated from Advice Filing p.AC-32 (Thermostat Set-back)

Baseline Energy Usage:

Cooing = Cooling Loads (kBtu/yr) x (1 ton-hr/12 kBtu) x 1.3 kW/ton
= 95,584 kBtu/yr x (1 ton-hr/12 kBtu) x 1.3 kW/ton
= 10,353
= 10,353 kWh/yr for San Jose

Heating = Heating Loads (kBtu/yr) x (1 therm/100 kBtu) x 1/Efficiency
= 184,203 kBtu/yr x (1 therm/100 kBtu) x 1/70%
= 2,631
= 2,631 therm/yr for San Jose

Revised Energy Use 7:00AM - 6:00PM

**Sample Heating and Cooling Load Calculations for San Jose**

| Outside Air (F) | Total Bin (hr/yr) | % OSA | Return Air (F) | Mixed Air (F) | Supply Air (F) | Cooling (kBtu/yr) | Heating (kBtu/yr) |
|---|---|---|---|---|---|---|---|
| 92 | 4 | 20% | 74 | 77.6 | 57 | 447 | 0 |
| 87 | 16 | 20% | 74 | 76.6 | 59 | 1,528 | 0 |
| 82 | 53 | 20% | 74 | 75.6 | 61 | 4,198 | 0 |
| 77 | 122 | 20% | 74 | 74.6 | 63 | 7,677 | 0 |
| 72 | 293 | 20% | 74 | 73.6 | 65 | 13,670 | 0 |
| 67 | 516 | 20% | 74 | 72.6 | 67 | 15,676 | 0 |
| 62 | 608 | 20% | 74 | 71.6 | 70 | 5,277 | 0 |
| 57 | 563 | 20% | 74 | 70.6 | 73 | 0 | 7,330 |
| 52 | 395 | 20% | 74 | 69.6 | 76 | 0 | 13,714 |
| 47 | 200 | 20% | 74 | 68.6 | 79 | 0 | 11,284 |
| 42 | 78 | 20% | 74 | 67.6 | 82 | 0 | 6,093 |
| 37 | 19 | 20% | 74 | 66.6 | 85 | 0 | 1,897 |
| 32 | 3 | 20% | 74 | 65.6 | 88 | 0 | 365 |
| 27 | 0 | 20% | 74 | 64.6 | 91 | 0 | 0 |
| Total | 2,870 | | | | Total | 48,473 | 40,683 |

Recreated from Advice Filing p.AC-32 (Thermostat Set-back)

Advice Filing lists total bin as 2,879 hours, but calculations do not support this.

Business Hours Energy Usage:

Cooling = Cooling Loads (kBtu/yr) x (1 ton-hr/12 kBtu) x 1.3 kW/ton
= 48,473 kBtu/yr x (1 ton-hr/12 kBtu) x 1.3 kW/ton
= 5,251
= 5,251 kWh/yr for San Jose

Heating = Heating Loads (kBtu/yr) x (1 therm/100 kBtu) x 1/Efficiency
= 40,683 kBtu/yr x (1 therm/100 kBtu) x 1/70%
= 581
= 581 therm/yr for San Jose

Revised Energy Use 7:00PM - 6:00AM

| Sample Heating and Cooling Load Calculations for San Jose | | | | | | | |
|---|---|---|---|---|---|---|---|
| Outside Air (F) | Total Bin (hr/yr) | % OSA | Return Air (F) | Mixed Air (F) | Supply Air (F) | Cooling (kBtu/yr) | Heating (kBtu/yr) |
| 92 | 2 | 20% | 74 | 77.6 | 62.0 | 169 | 0 |
| 87 | 8 | 20% | 74 | 76.6 | 64.0 | 547 | 0 |
| 82 | 31 | 20% | 74 | 75.6 | 66.0 | 1,614 | 0 |
| 77 | 85 | 20% | 74 | 74.6 | 68.0 | 3,043 | 0 |
| 72 | 242 | 20% | 74 | 73.6 | 73.6 | 0 | 0 |
| 67 | 561 | 20% | 74 | 72.6 | 72.6 | 0 | 0 |
| 62 | 1,146 | 20% | 74 | 71.6 | 71.6 | 0 | 0 |
| 57 | 1,414 | 20% | 74 | 70.6 | 70.6 | 0 | 0 |
| 52 | 1,150 | 20% | 74 | 69.6 | 71.0 | 0 | 8,734 |
| 47 | 735 | 20% | 74 | 68.6 | 74.0 | 0 | 21,532 |
| 42 | 373 | 20% | 74 | 67.6 | 77.0 | 0 | 19,021 |
| 37 | 119 | 20% | 74 | 66.6 | 80.0 | 0 | 8,651 |
| 32 | 21 | 20% | 74 | 65.6 | 83.0 | 0 | 1,982 |
| 27 | 1 | 20% | 74 | 64.6 | 86.0 | 0 | 116 |
| Total | 5,890 | | | | Total | 5,374 | 60,036 |

Recreated from Advice Filing p.AC-33 (Thermostat Set-back)

Setback Energy Usage:

Cooling = Cooling Loads (kBtu/yr) x (1 ton-hr/12 kBtu) x 1.3 kW/ton
= 5,374 kBtu/yr x (1 ton-hr/12 kBtu) x 1.3 kW/ton
= 582
= 582 kWh/yr for San Jose

Heating = Heating Loads (kBtu/yr) x (1 therm/100 kBtu) x 1/Efficiency
= 60,036 kBtu/yr x (1 therm/100 kBtu) x 1/70%
= 858
= 858 therm/yr for San Jose

Additional warm-up/cool-down loads:

Cooling = 19 F x (1hr/day x 3 mo/yr x 22 day/mo) x 1.085 Btu/cfm-deg-hr x 5,000 cfm
= 6,802,950
= 6,803 kBtu/yr

Heating = 11 F x (1hr/day x 3 mo/yr x 22 day/mo) x 1.085 Btu/cfm-deg-hr x 5,000 cfm
= 3,938,550
= 3,939 kBtu/yr

Total Retrofit Energy Use:

Cooling = 48,473 kBtu/yr + 5,373 kBtu/yr +3,939 kBtu/yr
= 57,785
Adjust to kWh = 57,785 kBtu/yr x (1 ton/12,000 Btu) x (1,000 Btu/kBtu)
= 4,815
= 4,815 ton/yr x 1.3 kW/ton
= 6,260
= 6,260 kWh/yr

Heating = 40,683 kBtu/yr + 60,036 kBtu/yr + 6,803 kBtu/yr
= 107,522
Adjust to Therm = 107,522 kBtu/yr x (1 therm/100,000 Btu) x (1,000 Btu/kBtu)
= 1,075
= 1,075 therm/yr x (1/70%)
= 1,536
= 1,536 therm/yr

Energy Savings:

Cooling = 10,353 kWh/yr - 6,260 kWh/yr
= 4,093
= 4,093 kWh/yr for a 10 ton unit — According to Advice Filing p. AC-33

Heating = 2,631 therms/yr - 1,536 therms/yr
= 1,095
= 1,095 therms/yr for a 250 kBtuh unit — According to Advice Filing p. AC-33

**4) Evaluation Estimates:**

For Baseline and Business Hours energy usage, see advice filing.

Revised Energy Use 7:00PM - 6:00AM

| Sample Heating and Cooling Load Calculations for San Jose | | | | | | | |
|---|---|---|---|---|---|---|---|
| Outside Air (F) | Total Bin (hr/yr) | % OSA | Return Air (F) | Mixed Air (F) | Supply Air (F) | Cooling (kBtu/yr) | Heating (kBtu/yr) |
| 92 | 2 | 20% | 85 | 86.4 | 82.2 | 46 | 0 |
| 87 | 8 | 20% | 85 | 85.4 | 84.2 | 52 | 0 |
| 82 | 31 | 20% | 85 | 84.4 | 86.2 | 0 | 0 |
| 77 | 85 | 20% | 85 | 83.4 | 88.2 | 0 | 0 |
| 72 | 242 | 20% | 85 | 82.4 | 90.2 | 0 | 0 |
| 67 | 561 | 20% | 85 | 81.4 | 92.2 | 0 | 0 |
| 62 | 1,148 | 20% | 85 | 80.4 | 94.2 | 0 | 0 |
| 57 | 1,414 | 20% | 85 | 79.4 | 101.8 | 0 | 0 |
| 52 | 1,150 | 20% | 55 | 54.4 | 56.8 | 0 | 14,973 |
| 47 | 735 | 20% | 55 | 53.4 | 59.8 | 0 | 25,519 |
| 42 | 373 | 20% | 55 | 52.4 | 62.8 | 0 | 21,045 |
| 37 | 119 | 20% | 55 | 51.4 | 65.8 | 0 | 9,296 |
| 32 | 21 | 20% | 55 | 50.4 | 68.8 | 0 | 2,096 |
| 27 | 1 | 20% | 55 | 49.4 | 71.8 | 0 | 122 |
| Total | 5,890 | | | | Total | 98 | 73,051 |

Recreated from Advice Filing p.AC-33 (Thermostat Set-back)

Setback Energy Usage:

Cooling = Cooling Loads (kBtu/yr) x (1 ton-hr/12 kBtu) x 1.3 kW/ton
= 5,374 kBtu/yr x (1 ton-hr/12 kBtu) x 1.3 kW/ton
= 11
= 11 kWh/yr

Heating = Heating Loads (kBtu/yr) x (1 ton-hr/100 kBtu) x 1/Efficiency
= 60,036 kBtu/yr x (1 therm/100 kBtu) x 1/70%
= 1,044
= 1,044 therms/yr

Total Retrofit Energy Use:

Assume same "ramping" used in the Advice Filing.

Cooling = 48,473 kBtu/yr + 98 kBtu/yr +3,939 kBtu/yr
= 52,510

Adjust to kWh = 52510 kBtu/yr x (1 ton/12,000 Btu) x (1,000 Btu/kBtu)
= 4,376
= 4,376 ton/yr x 1.3 kW/ton
= 5,689
= 5,689 kWh/yr

Heating = 40,683 kBtu/yr + 73,051 kBtu/yr + 6,803 kBtu/yr
= 120,537

Adjust to Therm = 120,573 kBtu/yr x (1 therm/100,000 Btu) x (1,000 Btu/kBtu)
= 1,205
= 1,205 therm/yr x (1/70%)
= 1,722
= 1,722 therm/yr

Energy Savings:

Cooling = 10,353 kWh/yr - 5,689 kWh/yr
= 4,664
= 4,664 kWh/yr for a 10 ton unit

Heating = 2,631 therms/yr - 1,722 therms/yr
= 909
= 909 therms/yr for a 250 kBtuh unit

**5) Summary of Results:**

| Impact Type (per 10-ton unit) | Impact: Advice Filing | Impact: Evaluation | Recommended Source |
|---|---|---|---|
| NC Demand (kW) | - | - | |
| Coinc. Demand (kW) | - | - | |
| Annual Energy (kWh | 4,093 | 4,664 | Evaluation |

Climate Zone Specific Impacts:

| Climate Zone | kWh/ton |
|---|---|
| CZ_1 | 73.4 |
| CZ_2 | 546.9 |
| CZ_3 | 253.3 |
| CZ_4 | 559.6 |
| CZ_5 | 305.9 |
| CZ_6 | 597.9 |
| CZ_7 | 764.2 |
| CZ_8 | 844.2 |
| CZ_9 | 942.2 |
| CZ_10 | 1059.4 |
| CZ_11 | 1043.7 |
| CZ_12 | 736.6 |
| CZ_13 | 1366.5 |
| CZ_14 | 1307.2 |
| CZ_15 | 2435.2 |
| CZ_16 | 489.2 |

**6) Adjust Energy Impacts by Conditioned Area:**

Advice Filing Assumptions:
Cooling Energy Savings = 4,664 kWh/yr for a 10 ton unit
= 466.4 kWh/yr-ton
Heating Energy Savings = 909 therms/yr for a 250 kBtuh unit
= 3.636 therms/yr-kBtuh

AC Sizing = 1 ton/500 sqft — According to Advice Filing p. AC-31

Furnace Sizing = 50 Btuh/sqft — According to Advice Filing p. AC-31

Evaluation Energy Estimate:
Cooling = (Conditioned Area) x (1 ton/500 sqft) x 466.4 kWh/yr-ton

Heating = (Conditioned Area) x (50 Btuh/sqft) x (3.636 therms/yr-kBtuh) x (1 kBtuh/1,000 Btuh)

## 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.<br><br>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:** | |

**Package Terminal AC**

**1) Install high efficiency PTAC and PTHP.**
Units must exceed Title 20 standards.

**2) Ex-ante Assumptions Used in Calculations:**

**Equivalent Full Load Cooling Hours**

| Market Segment | Hours/Year |
|---|---|
| Schools K-12 | 500 |
| Hotel/Motel | 700 |
| Grocery | 600 |
| College | 1,200 |
| Warehouse | 300 |
| Office | 1,000 |
| Hospitals | 1,900 |
| Other | 1,200 |
| Retail | 800 |
| Restaurant | 1,300 |
| Process Industry | 800 |
| Assembly Industry | 2,100 |

Advice Filing, Table 1, p. AC-4

EER = 10.0 - (0.16 x Capacity Btuh)

**3) Advice Filing Estimates:**

Demand Savings:

Measure Demand Savings = kW Title 20 - kW High Efficiency Unit, according to Advice Filing, p. AC-17

kW = 12 x tons/EER according to Advice Filing, p. AC-17

Measure Demand Savings

| Tons | Title 20 EER | Title 20 kW | igh Efficiency EER | High Efficiency kW | Demand Savings kW | Demand Savings kW/ton-EER |
|---|---|---|---|---|---|---|
| 0.6 | 8.9 | 0.809 | 9.5 | 0.758 | 0.051 | 0.142 |
| 0.8 | 8.6 | 1.116 | 9.6 | 1.000 | 0.116 | 0.145 |
| 1 | 8.0 | 1.500 | 9.1 | 1.319 | 0.181 | 0.165 |
| 1.3 | 7.6 | 2.053 | 9.1 | 1.714 | 0.338 | 0.174 |

Advice Filing p. AC-17 Average = 0.156

Advice Filing lists 0.157, the diff. is due to rounding

Coincident Demand Savings = Measure Demand Savings x 0.75 CDF
= 0.156 kW/ton-EER x 0.75 CDF
= 0.117
= 0.117 kW/ton-EER Advice Filing lists 0.118, the diff. is due to rounding

Energy Savings:

Annual Energy Savings = Measure Demand Savings x EFLCH
= 0.156 kW/ton-EER x EFLCH

**Coincident Energy Savings**

| Market Segment | Hours/Year | Annual Energy Savings kWh/ton-EER |
|---|---|---|
| Schools K-12 | 500 | 78 |
| Hotel/Motel | 700 | 109 |
| Grocery | 600 | 94 |
| College | 1,200 | 187 |
| Warehouse | 300 | 47 |
| Office | 1,000 | 156 |
| Hospitals | 1,900 | 296 |
| Other | 1,200 | 187 |
| Retail | 800 | 125 |
| Restaurant | 1,300 | 203 |
| Process Industry | 800 | 125 |
| Assembly Industry | 2,100 | 328 |

Advice Filing, p. AC-18

Values are slightly different than Advice Filing, due to using 0.156 kW/ton-EER as opposed to 0.157 kW/ton-EER

**4) Evaluation Estimates:**

Demand Savings:
EER is not linear.
For this reason, calculating an impact using the unit kW/ton-EER is only valid for a very small range of EER values.
Demand estimates are developed at a per unit basis.

Demand Savings = (Capacity, Btuh) x (1/EERtitle20 - 1/EERretrofit) x (1kW/1,000 Watts)
Coincident Demand Savings = Demand Savings x CDF
CDF = varies by climate zone and business type (0.75 used in sample calculations)

| Tons | Capacity Btuh | Title 20 EER | igh Efficiency EER | Demand Savings kW | Coincident Demand Savings kW |
|---|---|---|---|---|---|
| 0.6 | 7,200 | 8.9 | 9.5 | 0.051 | 0.038 |
| 0.8 | 9,600 | 8.6 | 9.6 | 0.116 | 0.087 |
| 1 | 12,000 | 8.0 | 9.1 | 0.181 | 0.136 |
| 1.3 | 15,600 | 7.6 | 9.1 | 0.338 | 0.254 |

Energy Savings:
Energy savings are also determined at a per unit level.
= Measure Demand Savings x EFLCH
= Assume 1 ton unit with 1.1 change in EER
= 0.181 kW/ton x EFLCH

**Sample Energy Savings Using 0.181 kW/ton**

| Market Segment | Hours/Year | Annual Energy Savings kWh |
|---|---|---|
| Schools K-12 | 500 | 91 |
| Hotel/Motel | 700 | 127 |
| Grocery | 600 | 109 |
| College | 1,200 | 217 |
| Warehouse | 300 | 54 |
| Office | 1,000 | 181 |
| Hospitals | 1,900 | 344 |
| Other | 1,200 | 217 |
| Retail | 800 | 145 |
| Restaurant | 1,300 | 235 |
| Process Industry | 800 | 145 |
| Assembly Industry | 2,100 | 380 |

## 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:** | |

**Reflective Window Film**

**1) Install reflective film on clear glass, non-North facing exposures.**

**2) Ex-ante Assumptions Used in Calculations:**

Clear glass SC = 0.95 ASHRAE 1993 Fundamentals p.27.19 table 11
Glass with reflective coating SC = 0.45 ASHRAE 1993 Fundamentals p.27.36 table 28
Solar data based on ASHRAE 1989 Fundamentals, p.27.10,latitude = 40 degrees
Radiation data multiplied by 75% to account for variations in shading and clearness.
Assume 75% fenestration for vertical surfaces.
Average cooling efficiency = 1.3 kW/ton
Conversion of kW/ton to EER:
= 1/[(1.3 kW/ton) x (1 ton/12 kBtu)]
= 9.23
= 9.23 Btu/W (EER)

Sample Building
Height = 30 ft
Footprint = 100 ft x 100 ft
Building Surface Area = 30,000 sqft
While building surface area is not needed for our analysis, the calculation is wrong.
Evaluation Building Surface Area = (4 x 100 ft x 30 ft) + 100 ft x 100 ft
= 22,000
= 22,000 sqft

Solar Load, South = 309 kBtu/sqft-yr
Solar Load, East-West = 241 kBtu/sqft-yr

**3) Advice Filing Estimates:**

Energy Savings:

Assume 2,250 sqft of glazing per orientation.

| Orientation | Area (sqft) | Solar Load (kBtu/sqft-yr) | Annual Solar Load (kBtu/yr) |
|---|---|---|---|
| South | 2,250 | 309 | 695,250 |
| East | 2,250 | 241 | 542,250 |
| West | 2,250 | 241 | 542,250 |
| Sum | 6,750 | | 1,779,750 |

Advice Filing table, p.AC-35

Baseline Solar Gain = 0.95 SC x 1,779,750 kBtu/yr
= 1,690,763
= 1,690,763 kBtu/yr
Retrofit Solar Gain = 0.45 SC x 1,779,750 kBtu/yr
= 800,888
= 800,888 kBtu/yr
Annual Energy Savings = (1,690,763 kBtu/yr) - 800,888 kBtu/yr
= 889,875
Adjust to kWh = 889,875 kBtu/yr x 1ton/12,000Btu/hr x 1,000 Btu/kBtu
= 74,156
= 74,156 ton-hr/yr x 1.3 kW/ton
= 96,403
= (96,403 kWh/yr)/6,750 sqft
= 14.28
= 14.28 kWh/sqft-yr

Demand Savings:

Advice Filing estimate:

| Orientation | Average Peak Gain (Btu/hr-sqft) |
|---|---|
| East | 216 |
| South | 33.3 |
| West | 25 |
| Total | 274.3 |
| Average | 91.43 |

Advice Filing, p.AC-36

Total Average Peak Gain = 274.3 Btu/sqft x 2,250 sqft
= 617,175

Alternate Calculation:
Total Average Peak Gain = 91.43 Btu/hr-yr x 6,750 sqft
= 617,153

Account for Load Time Delay = 617,175 Btu x 0.65 mass coefficient
= 401,164

Adjusted to kW = 401,164 Btu/hr x 1 ton/12,000 Btu/hr x 1.3 kW/ton
= 43.46
= 43 kW

Demand Savings =43 kW/6,750 sqft
= 0.0064
= 0.0064 kW/sqft

This would assume a 100% reduction in solar gains during the peak hour.

**4) Evaluation Estimates:**

Calculate Baseline Solar Gains Using ASHRAE Fundamentals†:

| Month | Half Day SHGF East (Btu/hr-sqft) | Half Day SHGF South (Btu/hr-sqft) | Half Day SHGF West (Btu/hr-sqft) | Daily SHGF East-West Btu/sqft-day | Annual SHGF East-West Btu/sqft-yr | Daily SHGF South Btu/sqft-day | Annual SHGF South Btu/sqft-yr |
|---|---|---|---|---|---|---|---|
| January | 452 | 813 | 62 | 514 | 15,934 | 1626 | 50,406 |
| February | 648 | 821 | 85 | 733 | 20,524 | 1642 | 45,976 |
| March | 832 | 694 | 114 | 946 | 29,326 | 1388 | 43,028 |
| April | 957 | 488 | 148 | 1105 | 33,150 | 976 | 29,280 |
| May | 1024 | 358 | 176 | 1200 | 37,200 | 716. | 22,196 |
| June | 1038 | 315 | 188 | 1226 | 36,780 | 630 | 18,900 |
| July | 1008 | 352 | 181 | 1189 | 36,859 | 704 | 21,824 |
| August | 928 | 474 | 157 | 1085 | 33,635 | 948 | 29,388 |
| September | 787 | 672 | 119 | 906 | 27,180 | 1344 | 40,320 |
| October | 623 | 791 | 89 | 712 | 22,072 | 1582 | 49,042 |
| November | 445 | 798 | 63 | 508 | 15,240 | 1596 | 47,880 |
| December | 374 | 775 | 53 | 427 | 13,237 | 1550 | 48,050 |
| | | | | Sum = | 321,137 | Sum = | 446,290 |

ASHRAE Fundamentals† p.27.23, Table 15

East-West Solar Gain = 321,137 Btu/sqft-yr x .75 shading factor
= 241
= 241 kBtu/sqft-yr

South Solar Gain = 446,290 Btu/sqft-yr x .75 shading factor
= 335
= 335 kBtu/sqft-yr

Advice Filing calculates 309 kBtu/sqft-yr for South solar gain, which is not consistent with the Evaluation estimate.
Application of a 75% shading factor renders this a conservative estimate.
Potential loads on unshaded surfaces could be as high as 100% of those estimated.

Calculate Baseline Peak Solar Gains Using ASHRAE Fundamentals†:

| | Peak Hour Solar Gains (Btu/hr-sqft) | | |
|---|---|---|---|
| | 8:00 AM, 4:00 PM | 9:00 AM, 3:00 PM | 10:00 AM, 2:00 PM |
| June (ave) | 90.67 | 89.67 | 83.00 |
| East | 216 | 192 | 145 |
| South | 29 | 45 | 69 |
| West | 27 | 32 | 35 |
| July (ave) | 90.67 | 92.00 | 87.33 |
| East | 216 | 193 | 146 |
| South | 30 | 52 | 81 |
| West | 26 | 31 | 35 |
| August (ave) | 93.33 | 101.67 | 99.33 |
| East | 216 | 197 | 150 |
| South | 41 | 80 | 116 |
| West | 23 | 28 | 32 |
| Average | 91.56 | 94.44 | 89.89 |
| East | **216** | 194 | 147 |
| South | **33.3** | 59 | 88.7 |
| West | **25.3** | 30.3 | 34 |

ASHRAE Fundamentals† p.27.23, Table 15

Peak solar gains occur during the 9:00 AM or 3:00 PM hour.
Advice Filing uses values from the 8:00 AM or 4:00 PM hour (in bold).

Energy Savings:
Assume 2,250 sqft of glazing per orientation.

| Orientation | Area (sqft) | Solar Load (kBtu/sqft-yr) | Annual Solar Load (kBtu/yr) |
|---|---|---|---|
| South | 2,250 | 335 | 753,750 |
| East | 2,250 | 241 | 542,250 |
| West | 2,250 | 241 | 542,250 |
| Sum | 6,750 | | 1,838,250 |

Advice Filing table, p.AC-35

Baseline Solar Gain = 0.95 SC x 1,838,250 kBtu/yr
= 1,746,338
= 1,746,338 kBtu/yr
Retrofit Solar Gain = 0.45 SC x 1,838,250 kBtu/yr
= 827,213
= 827,213 kBtu/yr
Annual Energy Savings = (1,746,338 kBtu/yr) - 827,213 kBtu/yr
= 919,125
Adjust to kWh = 919,125 kBtu/yr x 1ton/12,000Btu/hr x 1,000 Btu/kBtu
= 76,594
= 76,594 ton-hr/yr x 1.3 kW/ton
= 99,572
= (977,527 kWh/yr)/6,750 sqft
= 14.74
= 14.74 kWh/sqft-yr

Demand Savings:
Baseline Peak Gain = (216 Btu/sqft + 33.3 Btu/sqft +25.3 Btu/sqft) x 2,250 sqft
= 617,850
= 617,850 Btu x 0.95 SC
= 586,958
Adjust for Load Time Delay = 586,958 Btu x 0.65 mass coefficient factor
= 381,522
= 381,522 Btu

Retrofit Peak Gain = 617,850 Btu x 0.45 SC
= 278,033
Adjust for Load Time Delay = 278,033 Btu x 0.65 mass coefficient factor
= 180,721
= 180,721 Btu

Demand Savings = 381,522 Btu - 180,721 Btu
= 200,801
Adjusted to kW/sqft = (200,801 Btu x 1 ton/12,000 Btu/hr x 1.3 kW/ton)/6,750 sqft
= 0.0032
= 0.0032 kW/sqft

Coincident Demand Savings = 0.0032 kW/sqft x 0.75 CDF
= 0.0024
= 0.0024 kW/sqft

**5) Summary of Results:**

| Impact Type (per sqft of film) | Impact | | Recommended Source |
|---|---|---|---|
| | Advice Filing | Evaluation | |
| Coinc. Demand (kW) | 0.0064 | 0.0024 | Evaluation |
| Annual Energy (kWh) | 14.28 | 14.74 | Evaluation |

**6) Sources**

† ASHRAE Handbook, "Fundamentals"; American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
Atlanta, GA, 1993

## 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:** | Demand and energy savings were developed on a per ton basis for each climate zone using fan operating characteristics, temperature design conditions, and cooling degree hours. |
| **Comments on Advice Filing Calculations:** | Calculation methods cited in the Advice Filing do not accurately model participant specific retrofits. In some cases, negative demand and energy savings are calculated. |
| **Comments on Advice Filing Inputs:** | The inputs used in the calculations do not account for variations in evaporative cooler fan size. |
| **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. Impacts were developed using motor efficiency values listed in the baseline assumptions for the RE Motors program. |
| **Additional Notes:** | |

**Direct Evaporative Cooler**

**1) Replace an existing AC unit with an equally sized direct evaporative cooler.**

**2) Ex-ante calculation assumptions:**

1997 Advice Filing Assumptions
High comfort occupancy has an internal requirement of 76 F, 60% RH.
For a 5 F Δt between entering DB and interior design DB, the outside WB temp must be 64 F or lower.
Low comfort occupancy has an internal requirement of 84 F, 60% RH.
For a 5 F Δt between entering DB and interior design DB, the outside WB temp must be 72 F or lower.
4 hp of fan energy is required to move 12,000 cfm at 0.5 in static pressure.
This is consistent with manufactures' data.
Conventional HVAC system efficiency is 1.3 kW/ton.
To convert from hp to kW use 0.746 kW/hp.
The heat capacity of air is 1.08 Btu/hr-F-cfm.

**4) 1997 Advice Filing Estimates:**

The following estimates were developed by PG&E for the 1997 Advice Filing†.

Evaporative Capacity:

Q = cfm x Δt x 1.08 Btu/hr-F-cfm

where:
Q = evaporative capacity (Btu/hr)
cfm = cubic feet per minute
Δt = temperature differential between indoor design conditions and supply air temperature
that can be generated without exceeding the moisture ratio of the design conditions.
= Indoor design temp - {DB design temp - [70% effectiveness x (DB design temp - WB design temp)]}

| Climate Zone | DB Design temp (F) | WB Design temp (F) | Exit temp from evap. | Evaluation Δt (F) | Advice Filing Δt (F) | Capacity (Btu/hr) | Capacity (tons) |
|---|---|---|---|---|---|---|---|
| 2 | 90 | 65 | 72.5 | 11.5 | 11.5 | 149,040 | 12.42 |
| 4 | 83 | 71 | 74.6 | 8.0 | 8.0 | 103,680 | 8.64 |
| 5 | 77 | 65 | 68.6 | 15.4 | 15.4 | 199,584 | 16.63 |
| 11 | 96 | 66 | 75 | 9.0 | 9.0 | 116,640 | 9.72 |
| 12 | 93 | 68 | 75.5 | 8.5 | 8.5 | 110,160 | 9.18 |
| 13 | 99 | 71 | 79.4 | 4.6 | 4.6 | 59,616 | 4.97 |
| 16 | 99 | 63 | 73.8 | 10.2 | 10.2 | 132,192 | 11.02 |

Evaporator Fan Demand:

A 4 hp fan can move 12,000 cfm
= 4 hp x 0.746 kW/hp
= 2.984
= 2.984 kW

Demand Savings:

= baseline demand (kW/ton) - [fan demand (kW)/evaporator capacity (tons)]
= 1.3 kW/ton - 2.984 kW/capacity (tons)

Energy Savings:

= demand savings (kW/ton) x cooling degree hours (CDH)

| Climate Zone | emand Savings (kW/ton) | AF Dem. Savings (kW/ton) | CDH (hours) | Energy Savings (kWh/ton) | F Energy Savings (kWh/ton) |
|---|---|---|---|---|---|
| 2 | 1.06 | 1.04 | 1,003 | 1,063 | 1,043 |
| 4 | 0.95 | 0.93 | 861 | 822 | 801 |
| 5 | 1.12 | 1.11 | 493 | 552 | 547 |
| 11 | 0.99 | 0.97 | 1,729 | 1,717 | 1,677 |
| 12 | 0.97 | 0.95 | 1,331 | 1,298 | 1,264 |
| 13 | 0.70 | 0.65 | 2,252 | 1,575 | 1,464 |
| 16 | 1.03 | 1.01 | 720 | 741 | 727 |

**5) Evaluation Estimates:**

Use method described in the RE Motors program. (Advice Filing, p.MT-8).
Baseline efficiency for a 4 hp motor = 83%, according to Advice Filing p.MT-9
Load factor is assumed to be 75%, according to Advice Filing p.MT-8

Fan Demand:

= kW/hp x hp x 1/eff x % load
= 0.746 kW x 4 hp x (1/83% eff) x 75% load
= 2.696
= 2.696 kW/12,000 cfm

Demand Savings:

= [baseline demand (kW/ton)] - [fan demand (kW)/evaporator capacity (tons)]
= [(1.3 kW/ton)] - 2.696 kW/capacity (tons)

Coincident Demand Savings:

= [baseline demand (kW/ton) x CDF] - [fan demand (kW)/evaporator capacity (tons)]
= [(1.3 kW/ton) x 75%] - 2.696 kW/capacity (tons)

Energy Savings:

= demand savings (kW) x cooling degree hours (CDH)

**6) Summary of Results:**

| Climate Zone | Demand Savings | | Coincident Demand Savings | | Cooling Degree | Energy Savings | |
|---|---|---|---|---|---|---|---|
| | Evaluation (kW/ton) | 997 Advice Filing (kW/ton) | Evaluation (kW/ton) | 997 Advice Filing (kW/ton) | Hours (hours) | Evaluation (kWh/ton) | 97 Advice Filing (kWh/ton) |
| 2 | 1.08 | 1.04 | 0.76 | 0.78 | 1,003 | 1,086 | 1,043 |
| 4 | 0.99 | 0.93 | 0.66 | 0.698 | 861 | 851 | 801 |
| 5 | 1.14 | 1.11 | 0.81 | 0.833 | 493 | 561 | 547 |
| 11 | 1.02 | 0.97 | 0.70 | 0.728 | 1,729 | 1,768 | 1,677 |
| 12 | 1.01 | 0.95 | 0.68 | 0.713 | 1,331 | 1,339 | 1,265 |
| 13 | 0.76 | 0.65 | 0.43 | 0.488 | 2,252 | 1,705 | 1,464 |
| 16 | 1.06 | 1.01 | 0.73 | 0.758 | 720 | 760 | 727 |

**7) Sources**

† PG&E, "1997 Customer Energy Efficiency Programs, Advice Letter No. 1978-G/1608-E Workpapers"; pp. AC-23 to AC-25

**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:** | |

**Bypass Timer**

**1) Install a bypass timer for a zone intermittently occupied after hours when conditioning is scheduled off.**
Timer controls the fans of a central AC system.

**2) Ex-ante calculation assumptions:**
Average occupancy of zone is 2 hours per night.
Existing fan power = 1.0 hp.
Fans operate at 80% load/efficiency.
This value appears to be a combination of fan load and fan efficiency.
These two variables are independent of each other, and so should not be combined.
To convert from hp to kW use 0.746 kW/hp.
Baseline assumes fans are on for 11 hours a day, 260 days a year after business hours.
According to the Setback Programmable Thermostat measure, business hours are from 7:00 AM to 6:00 PM (11 hrs).
This implies that the system would be off for 13 hours (24 hr - 11 hr).
Retrofit assumes fans are on for 2 hours a day, 5 days a week after business hours.
Savings associated with the compressor are ignored, as night cooling loads are small due to low occupancy and low ambient temperatures.
Heating savings are not determined.

**3) Advice Filing Estimates:**

Baseline Energy Use:

= 1 hp x 0.746 kW/hp x 80% load/eff x 11 hrs/day x 260 days/yr
= 1,707
= 1,707 kWh/yr
Advice Filing lists 1,797 kWh/yr (AC-78)

Energy Savings:

= 1 hp x 0.746 kW/hp x 80% eff. x (11 - 2 hrs/day ) x 260 days/yr
= 1,397
= 1,397 kWh/yr
This is 82% of the baseline. 82%
Advice Filing also lists 82% (p.AC-78) which indicates that the 1,797 kWh/yr value was typed incorrectly.

NC Demand Savings:

= 1 hp x 0.746 kW/hp
= 0.746 kW

Cycle Peak Coincident Demand Savings:

= 0.746 kW x 0.82 x 0.75 CDF
= 0.459
= 0.459 kW
Demand savings is counted towards off-peak and partial-peak savings only, and is not applied to the MDSS.

**5) Evaluation Estimates:**

Use method described in the RE Motors proggram, (Advice Filing, p.MT-8).
Baseline efficiency for a 1 hp motor = 77%, according to Advice Filing p.MT-7
Load factor is assumed to be 80%, according to Advice Filing p.NRR-64

Baseline Energy Use:

= 1 hp x 0.746 kW/hp x (1/77% eff.) x 80% load x 11 hrs/day x 260 days/yr 0.9375
= 2,217
= 2,217 kWh/yr

Energy Savings:

= 1 hp x 0.746 kW/hp x (1/77% eff.) x 80% load x (11 - 2 hrs/day) x 260 days/yr
= 1,814
= 1,814 kWh/yr
This is 82% of the baseline. 82%

NC Demand Savings:

= kW x 1/eff x % load x (impact hours/baseline hours)
= 0.746 kW x (1/77% eff) x 80% load x (9 hrs/11 hrs)
= 0.634
= 0.634 kW

Coincident Demand Savings:

Since fans are assumed to run continuously during the peak period, the coincident demand savings are zero.

**6) Summary of Results:**

| Impact Type (per timer) | Impact | | Recommended Source |
|---|---|---|---|
| | Advice Filing | Evaluation | |
| Coinc. Demand (kW) | 0 | 0 | |
| Annual Energy (kWh) | 1,397 | 1,814 | Evaluation |

## Timeclock

| | |
|---|---|
| **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. |

**Timeclock - Electronic:**

**1) Installs electronic timeclocks in spaces with regular occupied and unoccupied periods.**

**2) Assumptions used in Advice Filing:**

Office hours = 07:00-18:00 M-F
Occupied Hours = 11 hr/day x 5 day/week x 52.14 week/yr
= 2,868
= Listed as 2,870 hr/year
AC size = 10 tons (120,000 Btu)
AC Efficiency = 1.3 kW/ton with out fans
EER = 9.23 Btu/Watt (calculated in spreadsheet "Window Film AF")
Area serviced/ton = 500 sqft/ton
Heating size = 250 kBtu/hr
Heating efficiency = 70%
Area served = 50 Btu/hr-sqft
Total cfm = 5,000
Fan hp = 3
Outside Supply Air = 20%
Location = San Jose, ASHRAE bin weather data

**A bin analysis method is used, where:**

OSA = outside air temp (F)
Bin = hours per year that temp is in a given range (hr/yr)
% OSA = percent outside air (fixed at 20%)
Ret Air = return air temp (F)
Mix Air = mixed air temperature
= (% OSA x OSA) + [(1 - % OSA) x Ret Air]
67 F = temp at which system switches from cooling to heating
SAT = supply air temp (F)
SAT (cooling) = 67 F + {[67 F - OSA)/5] x 2}
SAT (heating) = 67 F + {(67 F - OSA)/5] x 3}
Heating Loads (kBtu/yr) = [SAT - Mix Air (F)] x Bin (hr/yr) x (1.085 Btu/hr-F-CFM) x Air Flow (CFM)
Cooling Loads (kBtu/yr) = [Mix Air - SAT (F)] x Bin (hr/yr) x (1.085 Btu/hr-F-CFM) x Air Flow (CFM)

**Sample Heating and Cooling Load Calculations for San Jose**

| Outside Air (F) | Total Bin (hr/yr) | % OSA | Return Air (F) | Mixed Air (F) | Supply Air (F) | Cooling (kBtu/yr) | Heating (kBtu/yr) |
|---|---|---|---|---|---|---|---|
| 92 | 6 | 20% | 74 | 77.6 | 57 | 671 | 0 |
| 87 | 24 | 20% | 74 | 76.6 | 59 | 2,292 | 0 |
| 82 | 84 | 20% | 74 | 75.6 | 61 | 6,653 | 0 |
| 77 | 207 | 20% | 74 | 74.6 | 63 | 13,027 | 0 |
| 72 | 535 | 20% | 74 | 73.6 | 65 | 24,960 | 0 |
| 67 | 1,077 | 20% | 74 | 72.6 | 67 | 32,719 | 0 |
| 62 | 1,756 | 20% | 74 | 71.6 | 70 | 15,242 | 0 |
| 57 | 1,977 | 20% | 74 | 70.6 | 73 | 0 | 25,741 |
| 52 | 1,545 | 20% | 74 | 69.6 | 76 | 0 | 53,642 |
| 47 | 935 | 20% | 74 | 68.6 | 79 | 0 | 52,753 |
| 42 | 451 | 20% | 74 | 67.6 | 82 | 0 | 35,232 |
| 37 | 138 | 20% | 74 | 66.6 | 85 | 0 | 13,775 |
| 32 | 24 | 20% | 74 | 65.6 | 88 | 0 | 2,916 |
| 27 | 1 | 20% | 74 | 64.6 | 91 | 0 | 143 |
| Total | 8,760 | | | | Total | 95,564 | 184,203 |

Recreated from Advice Filing p.AC-28 (Thermostat Set-back)

Baseline Energy Usage:

Cooing = Cooling Loads (kBtu/yr) x (1 ton-hr/12 kBtu) x 1.3 kW/ton
= 95,564 kBtu/yr x (1 ton-hr/12 kBtu) x 1.3 kW/ton
= 10,353
= 10,353 kWh/yr for San Jose

Heating = Heating Loads (kBtu/yr) x (1 therm/100 kBtu) x 1/Efficiency
= 184,203 kBtu/yr x (1 therm/100 kBtu) x 1/70%
= 2,631
= 2,631 therm/yr for San Jose

Revised Energy Use 7:00AM - 6:00PM

**Sample Heating and Cooling Load Calculations for San Jose**

| Outside Air (F) | Total Bin (hr/yr) | % OSA | Return Air (F) | Mixed Air (F) | Supply Air (F) | Cooling (kBtu/yr) | Heating (kBtu/yr) |
|---|---|---|---|---|---|---|---|
| 92 | 4 | 20% | 74 | 77.6 | 57 | 447 | 0 |
| 87 | 16 | 20% | 74 | 76.6 | 59 | 1,528 | 0 |
| 82 | 53 | 20% | 74 | 75.6 | 61 | 4,198 | 0 |
| 77 | 122 | 20% | 74 | 74.6 | 63 | 7,677 | 0 |
| 72 | 293 | 20% | 74 | 73.6 | 65 | 13,670 | 0 |
| 67 | 516 | 20% | 74 | 72.6 | 67 | 15,676 | 0 |
| 62 | 608 | 20% | 74 | 71.6 | 70 | 5,277 | 0 |
| 57 | 563 | 20% | 74 | 70.6 | 73 | 0 | 7,330 |
| 52 | 395 | 20% | 74 | 69.6 | 76 | 0 | 13,714 |
| 47 | 200 | 20% | 74 | 68.6 | 79 | 0 | 11,284 |
| 42 | 78 | 20% | 74 | 67.6 | 82 | 0 | 6,093 |
| 37 | 19 | 20% | 74 | 66.6 | 85 | 0 | 1,897 |
| 32 | 3 | 20% | 74 | 65.6 | 88 | 0 | 365 |
| 27 | 0 | 20% | 74 | 64.6 | 91 | 0 | 0 |
| Total | 2,870 | | | | Total | 48,473 | 40,683 |

Advice Filing lists total bin as 2,879 hours, but calculations do not support this.

Recreated from Advice Filing p.AC-29 (Thermostat Set-back)

Business Hours Energy Usage:

```
        Cooling = Cooling Loads (kBtu/yr) x (1 ton-hr/12 kBtu) x 1.3 kW/ton
                = 48,473 kBtu/yr x (1 ton-hr/12 kBtu) x 1.3 kW/ton
                = 5,251
                = 5,251 kWh/yr for San Jose

        Heating = Heating Loads (kBtu/yr) x (1 therm/100 kBtu) x 1/Efficiency
                = 40,683 kBtu/yr x (1 therm/100 kBtu) x 1/70%
                = 581
                = 581 therm/yr for San Jose
```

Additional warm-up/cool-down loads:

```
        Cooling = 16 F x (1.5 hr/day x 3 mo/yr x 22 day/mo) x 1.085 Btu/cfm-deg-hr x 5,000 cfm
                = 8,593,200
                = 8,593 kBtu/yr

        Heating = 24 F x (1.5 hr/day x 3 mo/yr x 22 day/mo) x 1.085 Btu/cfm-deg-hr x 5,000 cfm
                = 12,889,800
                = 12,890 kBtu/yr
```

Total Retrofit Energy Use:

```
        Cooling = 48,473 kBtu/yr + 8,593 kBtu/yr
                = 57,066
  Adjust to kWh = 57,066 kBtu/yr x (1 ton/12,000 Btu) x (1,000 Btu/kBtu)
                = 4,756
                = 4,756 ton/yr x 1.3 kW/ton
                = 6,182
                = 6,182 kWh/yr

        Heating = 40,683 kBtu/yr + 12,890 kBtu/yr
                = 53,573
Adjust to Therm = 53,573 kBtu/yr x (1 therm/100,000 Btu) x (1,000 Btu/kBtu)
                = 536
                = 536 therm/yr x (1/70%)
                = 765
                = 765 therm/yr
```

Energy Savings:

```
        Cooling = 10,353 kWh/yr - 6,221 kWh/yr
                = 4,171
                = 4,171 kWh/yr for a 10 ton unit        According to Advice Filing p. AC-30

        Heating = 2,631 therms/yr - 765 therms/yr
                = 1,866
                = 1,866 therms/yr for a 250 kBtuh unit  According to Advice Filing p. AC-30
```

**4) Evaluation Estimates:**

See Advice Filing estimates for example using San Jose weather.
Impacts developed for all climate zones.

**5) Summary of Results:**

| Impact Type (per 10-ton unit) | Impact | | Recommended Source |
|---|---|---|---|
| | Advice Filing | Evaluation | |
| NC Demand (kW) | - | - | |
| Coinc. Demand (kW) | - | - | |
| Annual Energy (kWh) | 4,171 | 4,171 | Evaluation |

Climate Zone Specific Impacts:

| Climate Zone | kWh/ton |
|---|---|
| CZ_1 | 22.9 |
| CZ_2 | 523.4 |
| CZ_3 | 202.9 |
| CZ_4 | 514.7 |
| CZ_5 | 255.7 |
| CZ_6 | 547.6 |
| CZ_7 | 714.4 |
| CZ_8 | 807.3 |
| CZ_9 | 913.1 |
| CZ_10 | 1071.0 |
| CZ_11 | 1060.5 |
| CZ_12 | 722.5 |
| CZ_13 | 1407.9 |
| CZ_14 | 1364.6 |
| CZ_15 | 2731.7 |
| CZ_16 | 460.1 |

**6) Adjust Energy Impacts by Conditioned Area:**

Advice Filing Assumptions:

```
Cooling Energy Savings = 4,171 kWh/yr for a 10 ton unit
                       = 417.1 kWh/yr-ton
Heating Energy Savings = 1,866 therms/yr for a 250 kBtuh unit
                       = 7.464 therms/yr-kBtuh

             AC Sizing = 1 ton/500 sqft    According to Advice Filing p. AC-28

        Furnace Sizing = 50 Btuh/sqft      According to Advice Filing p. AC-28
```

Evaluation Energy Estimate:

Cooling = (Conditioned Area) x (1 ton/500 sqft) x 417.1 kWh/yr-ton

Heating = (Conditioned Area) x (50 Btuh/sqft) x (7.464 therms/yr-kBtuh) x (1 kBtuh/1,000 Btuh)

**Water and Evaporative Cooled Single Package AC Unit**

**(9135,000 Btu/hr)**

**Remote Condensing Unit (RCU); Air-Cooled**

**(9135,000 Btu/hr)**

**Remote Condensing Unit (RCU); Water- and Evaporative- Cooled (9135,000 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 Title20 standards.<br><br>Sufficient data are not available to verify either the CDF or the EFLH values used in the calculation.<br><br>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. |

**Water and Evaporative Cooled Single-Package AC Unit**
**Remote Condensing Unit (RCU); Air-Cooled**
**Remote Condensing Unit (RCU); Water and Evaporative Cooled**

**1) Installation of high-efficiency AC units using the different technologies described.**
Units must exceed Title 20 standards.

**2) Ex-ante Assumptions Used in Calculations:**
Baseline Title20 Efficiencies:
Evap Single-Package AC = 9.6 EER
RCU Air-cooled = 9.9 EER
RCU Evap-cooled = 12.9 EER
These values were verified using CEC documentation.

**Equivalent Full Load Cooling Hours**

| Market Segment | Hours/Year |
|---|---|
| Schools K-12 | 500 |
| Hotel/Motel | 700 |
| Grocery | 600 |
| College | 1,200 |
| Warehouse | 300 |
| Office | 1,000 |
| Hospitals | 1,900 |
| Other | 1,200 |
| Retail | 800 |
| Restaurant | 1,300 |
| Process Industry | 800 |
| Assembly Industry | 2,100 |

Advice Filing, Table 1, p. AC-3

**3) Advice Filing Estimates:**

Demand Savings:
Measure Demand Savings = kW Title 20 - kW High Efficiency Unit, according to Advice Filing, p. AC-15

kW = (12,000 Btuh/ton) x (1kW/1,000Watt) x (tons/EER Btuh/Watt) according to Advice Filing, p. AC-15
Coincident Demand Savings = Measure Demand Savings x 0.75 CDF

Demand Savings

| Program | Tons | Title 20 EER | Title 20 kW | High Efficiency EER | High Efficiency kW | Demand Savings kW | Demand Savings kW/ton-EER | Coinc kW Savings kW/ton-EER |
|---|---|---|---|---|---|---|---|---|
| Evap. Cooled SPAC | 80 | 9.6 | 100.000 | 10.5 | 91.429 | 8.571 | 0.119 | |
| | 80 | 9.6 | 100.000 | 11.5 | 83.478 | 16.522 | 0.109 | |
| | | | | | | **Average** | **0.114** | **0.085** |
| Air-Cooled RCU | 30 | 9.9 | 36.364 | 10.2 | 35.294 | 1.070 | 0.119 | |
| | 60 | 9.9 | 72.727 | 10.5 | 68.571 | 4.156 | 0.115 | |
| | | | | | | **Average** | **0.117** | **0.088** |
| Evap-Cooled RCU | 80 | 12.9 | 74.419 | 13.5 | 71.111 | 3.307 | 0.069 | |
| | 120 | 12.9 | 111.628 | 14 | 102.857 | 8.771 | 0.066 | |
| | | | | | | **Average** | **0.068** | **0.051** |

Advice Filing p. AC-15-22
Values may vary slightly due to rounding.

Energy Savings:
Annual Energy Savings = Measure Demand Savings x EFLCH

**Coincident Energy Savings**

| Market Segment | Hours/Year | Evap Cooled SPAC Annual Energy Savings kWh/ton-EER | Air-Cooled RCU Annual Energy Savings kWh/ton-EER | Evap-Cooled RCU Annual Energy Savings kWh/ton-EER |
|---|---|---|---|---|
| Schools K-12 | 500 | 57 | 59 | 34 |
| Hotel/Motel | 700 | 80 | 82 | 47 |
| Grocery | 600 | 68 | 70 | 41 |
| College | 1,200 | 137 | 141 | 81 |
| Warehouse | 300 | 34 | 35 | 20 |
| Office | 1,000 | 114 | 117 | 68 |
| Hospitals | 1,900 | 216 | 223 | 129 |
| Other | 1,200 | 137 | 141 | 81 |
| Retail | 800 | 91 | 94 | 54 |
| Restaurant | 1,300 | 148 | 152 | 88 |
| Process Industry | 800 | 91 | 94 | 54 |
| Assembly Industry | 2,100 | 239 | 246 | 142 |

Advice Filing p. AC-15-22
Values may vary slightly due to rounding.

**4) Evaluation Estimates:**

Demand Savings:

EER is not linear.
For this reason, calculating an impact using the unit kW/ton-EER is only valid for a very small range of EER values.
Demand estimates are developed at a per unit basis.

Demand Savings = (Capacity, Btuh) x (1/EERtitle20 - 1/EERretrofit) x (1kW/1,000 Watts)
Coincident Demand Savings = Demand Savings x CDF
CDF = varies by climate zone and business type

Energy Savings:
Use EFLH's and CDF's developed for the CAC measures for each climate zone.

Energy Savings = Demand Savings x EFLH (climate zone specific)

No efficiency value recorded in the MDSS for the single participant in the RCU Evap-cooled measure.
Using the baseline efficiencies and the kW and kWh impacts, the retrofit efficiency was determined through back-calculations.
Back-calculated Efficiency:
3.723 kW = 0.068 kW/ton- EER x 36.5 tons x (EER - 12.9 EER) x 0.75 CDF
EER = [3.723 kW/(0.068 kW/ton- EER x 36.5 tons x 0.75 CDF)] + 12.9
= 14.9
= 14.9 EER according to kW impacts

3,416.4 kWh = 34 kWh/ton- EER x 36.5 tons x (EER - 12.9 EER)
EER = 15.65
= 15.65 EER according to kWh impacts

Average EER = 15.28

***Attachment 3***

***Results Tables***

## *Attachment 3-1*
## *Commercial HVAC Ex Ante Gross Energy Impacts*
## *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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 76,569 | 24,061 | 49,140 | 21,438 | - | 34,824 | 49,937 | 1,017 | - | 16,785 | 55,929 | 6,746 | 336,445 |
| | Adjustable Speed Drives | 180,753 | - | - | - | - | - | - | - | - | 75,314 | 52,720 | - | 308,787 |
| | Package Terminal A/C | 2,337 | - | - | 603 | - | 8,405 | - | 28,967 | - | - | - | - | 40,312 |
| | Set-Back Thermostat | 57,312 | 16,375 | - | 85,969 | - | 12,281 | - | - | - | 12,281 | 49,125 | 4,094 | 237,437 |
| | Reflective Window Film | 110,771 | - | 3,342 | - | - | 2,252 | 73,298 | - | 14,640 | 13,140 | 3,071 | - | 220,514 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 22,804 | - | 22,804 |
| | Other HVAC Technologies | - | - | - | - | 40,255 | - | - | - | - | - | - | - | 40,255 |
| | Retrofit Express Program Total | 427,743 | 40,436 | 52,482 | 108,010 | 40,255 | 57,763 | 123,235 | 29,983 | 14,640 | 117,520 | 183,649 | 10,840 | 1,206,555 |
| REO | Adjustable Speed Drives | 372,699 | - | - | - | - | - | - | - | - | - | - | - | 372,699 |
| | Water Chillers | 49,918 | - | 385,018 | 159,529 | - | - | - | - | - | - | 210,879 | - | 805,343 |
| | Cooling Towers | - | - | 168,591 | 80,527 | - | - | 105,219 | - | - | - | 71,925 | - | 426,262 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Retrofit Efficiency Options Program Total | | 422,617 | 0 | 553,609 | 240,056 | 0 | 0 | 105,219 | 0 | 0 | 0 | 282,803 | 0 | 1,604,304 |
| APO | Water Chillers | 2,678,480 | - | - | - | - | - | 1,730,494 | - | - | 1,529,262 | 2,976,298 | - | 8,914,534 |
| | Customized EMS | 559,083 | - | 376,640 | - | - | - | 355,177 | - | - | 1,283,884 | - | - | 2,574,785 |
| | Customized Controls | 512,804 | - | - | - | - | - | 118,305 | - | - | - | - | - | 631,109 |
| | Convert To VAV | 530,960 | 33,789 | - | - | - | - | - | - | - | - | - | - | 564,749 |
| | Other Customized Equip | 1,377,912 | - | 1,443,435 | - | - | - | - | 1,025,634 | - | - | - | - | 3,846,982 |
| | Other HVAC Technologies | 230,772 | - | - | - | - | - | - | - | - | - | 1,098,003 | - | 1,328,775 |
| Advanced Performance Options Program Total | | 5,890,012 | 33,789 | 1,820,075 | 0 | 0 | 0 | 2,203,976 | 1,025,634 | 0 | 2,813,146 | 4,074,301 | 0 | 17,860,934 |
| **Total** | | 6,740,372 | 74,225 | 2,426,166 | 348,066 | 40,255 | 57,763 | 2,432,430 | 1,055,617 | 14,640 | 2,930,666 | 4,540,753 | 10,840 | **20,671,794** |

*Attachment 3-2*
***Commercial HVAC Ex Ante Net Energy Impacts***
***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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 58,947 | 18,524 | 37,831 | 16,504 | - | 26,810 | 38,444 | 783 | - | 12,922 | 43,057 | 5,193 | 259,015 |
| | Adjustable Speed Drives | 139,154 | - | - | - | - | - | - | - | - | 57,981 | 40,587 | - | 237,722 |
| | Package Terminal A/C | 1,799 | - | - | 464 | - | 6,471 | - | 22,300 | - | - | - | - | 31,035 |
| | Set-Back Thermostat | 44,123 | 12,606 | - | 66,184 | - | 9,455 | - | - | - | 9,455 | 37,819 | 3,152 | 182,793 |
| | Reflective Window Film | 85,278 | - | 2,573 | - | - | 1,734 | 56,429 | - | 11,270 | 10,116 | 2,364 | - | 169,765 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 17,556 | - | 17,556 |
| | Other HVAC Technologies | - | - | - | - | 30,991 | - | - | - | - | - | - | - | 30,991 |
| Retrofit Express Program Total | | 329,302 | 31,130 | 40,404 | 83,152 | 30,991 | 44,470 | 94,874 | 23,083 | 11,270 | 90,474 | 141,384 | 8,345 | 928,877 |
| REO | Adjustable Speed Drives | 279,473 | - | - | - | - | - | - | - | - | - | - | - | 279,473 |
| | Water Chillers | 37,431 | - | 288,711 | 119,625 | - | - | - | - | - | - | 158,130 | - | 603,897 |
| | Cooling Towers | - | - | 126,420 | 60,384 | - | - | 78,900 | - | - | - | 53,934 | - | 319,638 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Retrofit Efficiency Options Program Total | | 316,905 | 0 | 415,131 | 180,009 | 0 | 0 | 78,900 | 0 | 0 | 0 | 212,064 | 0 | 1,203,008 |
| APO | Water Chillers | 2,008,492 | - | - | - | - | - | 1,297,633 | - | - | 1,146,737 | 2,231,815 | - | 6,684,676 |
| | Customized EMS | 419,236 | - | 282,428 | - | - | - | 266,334 | - | - | 962,737 | - | - | 1,930,735 |
| | Customized Controls | 384,533 | - | - | - | - | - | 88,712 | - | - | - | - | - | 473,245 |
| | Convert To VAV | 398,147 | 25,337 | - | - | - | - | - | - | - | - | - | - | 423,485 |
| | Other Customized Equip | 1,033,245 | - | 1,082,378 | - | - | - | - | 769,085 | - | - | - | - | 2,884,708 |
| | Other HVAC Technologies | 173,048 | - | - | - | - | - | - | - | - | - | 823,352 | - | 996,399 |
| Advanced Performance Options Program Total | | 4,416,700 | 25,337 | 1,364,807 | 0 | 0 | 0 | 1,652,679 | 769,085 | 0 | 2,109,473 | 3,055,166 | 0 | 13,393,247 |
| **Total** | | 5,062,906 | 56,467 | 1,820,341 | 263,161 | 30,991 | 44,470 | 1,826,453 | 792,167 | 11,270 | 2,199,947 | 3,408,613 | 8,345 | **15,525,132** |

*Attachment 3-3*
***Commercial HVAC Unadjusted Engineering Energy Impacts***
***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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 69,294 | 11,668 | 6,813 | 6,614 | - | 27,626 | 29,911 | 1,615 | - | 15,074 | 40,645 | 6,540 | 215,802 |
| | Adjustable Speed Drives | 333,685 | - | - | - | - | - | - | - | - | 155,283 | 135,583 | - | 624,550 |
| | Package Terminal A/C | 2,402 | - | - | 748 | - | 6,987 | - | 24,554 | - | - | - | - | 34,691 |
| | Set-Back Thermostat | 27,335 | 14,168 | - | 44,196 | - | 5,788 | - | - | - | 6,782 | 35,342 | 5,466 | 139,076 |
| | Reflective Window Film | 114,319 | - | 3,449 | - | - | 2,324 | 75,646 | - | 15,109 | 13,561 | 3,169 | - | 227,577 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 22,804 | - | 22,804 |
| | Other HVAC Technologies | - | - | - | - | 41,496 | - | - | - | - | - | - | - | 41,496 |
| Retrofit Express Program Total | | 547,035 | 25,836 | 10,263 | 51,558 | 41,496 | 42,726 | 105,557 | 26,169 | 15,109 | 190,699 | 237,544 | 12,006 | 1,305,997 |
| REO | Adjustable Speed Drives | 266,434 | - | - | - | - | - | - | - | - | - | - | - | 266,434 |
| | Water Chillers | 59,870 | - | 81,659 | 117,548 | - | - | - | - | - | - | 79,928 | - | 339,005 |
| | Cooling Towers | - | - | 36,861 | 24,091 | - | - | 105,219 | - | - | - | 13,974 | - | 180,145 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Retrofit Efficiency Options Program Total | | 326,305 | 0 | 118,520 | 141,639 | 0 | 0 | 105,219 | 0 | 0 | 0 | 93,901 | 0 | 785,585 |
| APO | Water Chillers | 1,494,373 | - | - | - | - | - | 620,280 | - | - | 1,529,262 | 2,976,298 | - | 6,620,213 |
| | Customized EMS | 76,911 | - | 376,640 | - | - | - | - | - | - | 1,283,884 | - | - | 1,737,435 |
| | Customized Controls | 789,661 | - | - | - | - | - | 109,803 | - | - | - | - | - | 899,464 |
| | Convert To VAV | 530,960 | 35,742 | - | - | - | - | - | - | - | - | - | - | 566,702 |
| | Other Customized Equip | 1,377,912 | - | 1,451,248 | - | - | - | - | 1,076,035 | - | - | - | - | 3,905,195 |
| | Other HVAC Technologies | 305,851 | - | - | - | - | - | - | - | - | - | 1,098,003 | - | 1,403,855 |
| Advanced Performance Options Program Total | | 4,575,669 | 35,742 | 1,827,888 | 0 | 0 | 0 | 730,083 | 1,076,035 | 0 | 2,813,146 | 4,074,301 | 0 | 15,132,865 |
| **Total** | | 5,449,009 | 61,578 | 1,956,671 | 193,198 | 41,496 | 42,726 | 940,859 | 1,102,204 | 15,109 | 3,003,845 | 4,405,746 | 12,006 | **17,224,446** |

*Attachment 3-4*

***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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | [redacted] |
| | Adjustable Speed Drives | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | [redacted] |
| | Package Terminal A/C | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | [redacted] |
| | Set-Back Thermostat | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | [redacted] |
| | Reflective Window Film | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | [redacted] |
| | Water Chillers | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | [redacted] |
| | Other HVAC Technologies | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | [redacted] |
| Retrofit Express Program Total | | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| REO | Adjustable Speed Drives | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | [redacted] |
| | Water Chillers | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | [redacted] |
| | Cooling Towers | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | [redacted] |
| | High Efficiency Gas Boilers | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | [redacted] |
| Retrofit Efficiency Options Program Total | | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| APO | Water Chillers | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | [redacted] |
| | Customized EMS | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | [redacted] |
| | Customized Controls | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | [redacted] |
| | Convert To VAV | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | [redacted] |
| | Other Customized Equip | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | [redacted] |
| | Other HVAC Technologies | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | 0.76 | [redacted] |
| Advanced Performance Options Program Total | | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| Total | | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | 0.79 |

## *Attachment 3-5*
## *Commercial HVAC Ex Post Gross Energy Impacts*
## *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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 79,745 | 13,428 | 7,841 | 7,612 | - | 31,793 | 34,422 | 1,858 | - | 17,348 | 46,775 | 7,526 | 248,348 |
| | Adjustable Speed Drives | 384,010 | - | - | - | - | - | - | - | - | 178,701 | 156,031 | - | 718,742 |
| | Package Terminal A/C | 2,765 | - | - | 861 | - | 8,040 | - | 28,257 | - | - | - | - | 39,923 |
| | Set-Back Thermostat | 31,457 | 16,304 | - | 50,861 | - | 6,661 | - | - | - | 7,804 | 40,673 | 6,290 | 160,051 |
| | Reflective Window Film | 131,560 | - | 3,969 | - | - | 2,675 | 87,054 | - | 17,387 | 15,606 | 3,647 | - | 261,899 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 17,278 | - | 17,278 |
| | Other HVAC Technologies | - | - | - | - | 47,754 | - | - | - | - | - | - | - | 47,754 |
| | Retrofit Express Program Total | 629,536 | 29,732 | 11,810 | 59,334 | 47,754 | 49,170 | 121,477 | 30,115 | 17,387 | 219,459 | 264,404 | 13,817 | 1,493,995 |
| REO | Adjustable Speed Drives | 306,617 | - | - | - | - | - | - | - | - | - | - | - | 306,617 |
| | Water Chillers | 45,363 | - | 61,872 | 89,065 | - | - | - | - | - | - | 60,560 | - | 256,860 |
| | Cooling Towers | - | - | 27,929 | 18,254 | - | - | 79,723 | - | - | - | 10,588 | - | 136,494 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Retrofit Efficiency Options Program Total | | 351,980 | 0 | 89,801 | 107,318 | 0 | 0 | 79,723 | 0 | 0 | 0 | 71,148 | 0 | 699,971 |
| APO | Water Chillers | 1,132,270 | - | - | - | - | - | 469,979 | - | - | 1,158,705 | 2,255,108 | - | 5,016,062 |
| | Customized EMS | 58,275 | - | 285,376 | - | - | - | - | - | - | 972,785 | - | - | 1,316,436 |
| | Customized Controls | 598,318 | - | - | - | - | - | 83,196 | - | - | - | - | - | 681,514 |
| | Convert To VAV | 402,303 | 27,081 | - | - | - | - | - | - | - | - | - | - | 429,384 |
| | Other Customized Equip | 1,044,029 | - | 1,099,595 | - | - | - | - | 815,300 | - | - | - | - | 2,958,924 |
| | Other HVAC Technologies | 231,740 | - | - | - | - | - | - | - | - | - | 831,945 | - | 1,063,685 |
| Advanced Performance Options Program Total | | 3,466,934 | 27,081 | 1,384,971 | 0 | 0 | 0 | 553,175 | 815,300 | 0 | 2,131,490 | 3,087,053 | 0 | 11,466,005 |
| **Total** | | 4,448,450 | 56,814 | 1,486,582 | 166,653 | 47,754 | 49,170 | 754,376 | 845,415 | 17,387 | 2,350,949 | 3,422,605 | 13,817 | **13,659,972** |

## *Attachment 3-6*
## *Commercial HVAC Gross Energy Impact Realization Rates*
## *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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 1.04 | 0.56 | 0.16 | 0.36 | - | 0.91 | 0.69 | 1.83 | - | 1.03 | 0.84 | 1.12 | 0.74 |
| | Adjustable Speed Drives | 2.12 | - | - | - | - | - | - | - | - | 2.37 | 2.96 | - | 2.33 |
| | Package Terminal A/C | 1.18 | - | - | 1.43 | - | 0.96 | - | 0.98 | - | - | - | - | 0.99 |
| | Set-Back Thermostat | 0.55 | 1.00 | - | 0.59 | - | 0.54 | - | - | - | 0.64 | 0.83 | 1.54 | 0.67 |
| | Reflective Window Film | 1.19 | - | 1.19 | - | - | 1.19 | 1.19 | - | 1.19 | 1.19 | 1.19 | - | 1.19 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 0.76 | - | 0.76 |
| | Other HVAC Technologies | - | - | - | - | 1.19 | - | - | - | - | - | - | - | 1.19 |
| Retrofit Express Program Total | | 1.47 | 0.74 | 0.23 | 0.55 | 1.19 | 0.85 | 0.99 | 1.00 | 1.19 | 1.87 | 1.44 | 1.27 | 1.24 |
| REO | Adjustable Speed Drives | 0.82 | - | - | - | - | - | - | - | - | - | - | - | 0.82 |
| | Water Chillers | 0.91 | - | 0.16 | 0.56 | - | - | - | - | - | - | 0.29 | - | 0.32 |
| | Cooling Towers | - | - | 0.17 | 0.23 | - | - | 0.76 | - | - | - | 0.15 | - | 0.32 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Retrofit Efficiency Options Program Total | | 0.83 | - | 0.16 | 0.45 | - | - | 0.76 | - | - | - | 0.25 | - | 0.44 |
| APO | Water Chillers | 0.42 | - | - | - | - | - | 0.27 | - | - | 0.76 | 0.76 | - | 0.56 |
| | Customized EMS | 0.10 | - | 0.76 | - | - | - | - | - | - | 0.76 | - | - | 0.51 |
| | Customized Controls | 1.17 | - | - | - | - | - | 0.70 | - | - | - | - | - | 1.08 |
| | Convert To VAV | 0.76 | 0.80 | - | - | - | - | - | - | - | - | - | - | 0.76 |
| | Other Customized Equip | 0.76 | - | 0.76 | - | - | - | - | 0.79 | - | - | - | - | 0.77 |
| | Other HVAC Technologies | 1.00 | - | - | - | - | - | - | - | - | - | 0.76 | - | 0.80 |
| Advanced Performance Options Program Total | | 0.59 | 0.80 | 0.76 | - | - | - | 0.25 | 0.79 | - | 0.76 | 0.76 | - | 0.64 |
| **Total** | | 0.66 | 0.77 | 0.61 | 0.48 | 1.19 | 0.85 | 0.31 | 0.80 | 1.19 | 0.80 | 0.75 | 1.27 | **0.66** |

## *Attachment 3-7*
## *Commercial HVAC Net-to-Gross Adjustments*
## *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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 |
| | Adjustable Speed Drives | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 |
| | Package Terminal A/C | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 |
| | Set-Back Thermostat | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |
| | Reflective Window Film | 0.36 | 0.36 | 0.36 | 0.36 | . 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 |
| | Water Chillers | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Other HVAC Technologies | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| Retrofit Express Program Total | | 0.64 | 0.65 | 0.51 | 0.69 | 0.14 | 0.66 | 0.43 | 1.01 | 0.36 | 0.69 | 0.71 | 0.64 | 0.63 |
| REO | Adjustable Speed Drives | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 |
| | Water Chillers | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.88 |
| | Cooling Towers | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | High Efficiency Gas Boilers | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | [illegible] |
| Retrofit Efficiency Options Program Total | | 0.75 | [illegible] | 0.90 | 0.90 | [illegible] | [illegible] | 0.90 | [illegible] | [illegible] | [illegible] | 0.90 | [illegible] | 0.83 |
| APO | Water Chillers | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Customized EMS | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Customized Controls | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Convert To VAV | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Other Customized Equip | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Other HVAC Technologies | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| Advanced Performance Options Program Total | | 0.90 | 0.90 | 0.90 | [illegible] | [illegible] | [illegible] | 0.90 | 0.90 | [illegible] | 0.90 | 0.90 | [illegible] | 0.90 |
| **Total** | | 0.85 | 0.77 | 0.90 | 0.83 | 0.14 | 0.66 | 0.83 | 0.91 | 0.36 | 0.88 | 0.89 | 0.64 | 0.87 |

## *Attachment 3-8*
## *Commercial HVAC Ex Post Net Energy Impacts*
## *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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 46,939 | 7,904 | 4,615 | 4,480 | - | 18,714 | 20,262 | 1,094 | - | 10,211 | 27,533 | 4,430 | 146,182 |
| | Adjustable Speed Drives | 281,563 | - | - | - | - | - | - | - | - | 131,027 | 114,404 | - | 526,994 |
| | Package Terminal A/C | 2,864 | - | - | 892 | - | 8,328 | - | 29,270 | - | - | - | - | 41,353 |
| | Set-Back Thermostat | 22,024 | 11,415 | - | 35,609 | - | 4,664 | - | - | - | 5,464 | 28,476 | 4,404 | 112,055 |
| | Reflective Window Film | 47,423 | - | 1,431 | - | - | 964 | 31,380 | - | 6,267 | 5,625 | 1,315 | - | 94,406 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 15,585 | - | 15,585 |
| | Other HVAC Technologies | - | - | - | - | 6,691 | - | - | - | - | - | - | - | 6,691 |
| | Retrofit Express Program Total | 400,812 | 19,319 | 6,046 | 40,981 | 6,691 | 32,670 | 51,642 | 30,363 | 6,267 | 152,328 | 187,313 | 8,834 | 943,267 |
| REO | Adjustable Speed Drives | 224,817 | - | - | - | - | - | - | - | - | - | - | - | 224,817 |
| | Water Chillers | 40,918 | - | 55,810 | 80,338 | - | - | - | - | - | - | 54,626 | - | 231,692 |
| | Cooling Towers | - | - | 25,193 | 16,465 | - | - | 71,912 | - | - | - | 9,550 | - | 123,120 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Retrofit Efficiency Options Program Total | | 265,735 | 0 | 81,002 | 96,803 | 0 | 0 | 71,912 | 0 | 0 | 0 | 64,177 | 0 | 579,629 |
| APO | Water Chillers | 1,021,327 | - | - | - | - | - | 423,929 | - | - | 1,045,173 | 2,034,148 | - | 4,524,577 |
| | Customized EMS | 52,565 | - | 257,414 | - | - | - | - | - | - | 877,469 | - | - | 1,187,448 |
| | Customized Controls | 539,693 | - | - | - | - | - | 75,045 | - | - | - | - | - | 614,738 |
| | Convert To VAV | 362,884 | 24,428 | - | - | - | - | - | - | - | - | - | - | 387,312 |
| | Other Customized Equip | 941,733 | - | 991,854 | - | - | - | - | 735,415 | - | - | - | - | 2,669,002 |
| | Other HVAC Technologies | 209,034 | - | - | - | - | - | - | - | - | - | 750,429 | - | 959,463 |
| Advanced Performance Options Program Total | | 3,127,236 | 24,428 | 1,249,268 | 0 | 0 | 0 | 498,974 | 735,415 | 0 | 1,922,642 | 2,784,577 | 0 | 10,342,540 |
| **Total** | | 3,793,784 | 43,747 | 1,336,317 | 137,784 | 6,691 | 32,670 | 622,528 | 765,778 | 6,267 | 2,074,969 | 3,036,066 | 8,834 | **11,865,436** |

## *Attachment 3-9*
## *Commercial HVAC Net Energy Impact Realization Rates*
## *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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 0.80 | 0.43 | 0.12 | 0.27 | - | 0.70 | 0.53 | 1.40 | - | 0.79 | 0.64 | 0.85 | 0.56 |
| | Adjustable Speed Drives | 2.02 | - | - | - | - | - | - | - | - | 2.26 | 2.82 | - | 2.22 |
| | Package Terminal A/C | 1.59 | - | - | 1.92 | - | 1.29 | - | 1.31 | - | - | - | - | 1.33 |
| | Set-Back Thermostat | 0.50 | 0.91 | - | 0.54 | - | 0.49 | - | - | - | 0.58 | 0.75 | 1.40 | 0.61 |
| | Reflective Window Film | 0.56 | - | 0.56 | - | - | 0.56 | 0.56 | - | 0.56 | 0.56 | 0.56 | - | 0.56 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 0.89 | - | 0.89 |
| | Other HVAC Technologies | - | - | - | - | 0.22 | - | - | - | - | - | - | - | 0.22 |
| Retrofit Express Program Total | | 1.22 | 0.62 | 0.15 | 0.49 | 0.22 | 0.73 | 0.54 | 1.32 | 0.56 | 1.68 | 1.32 | 1.06 | 1.02 |
| REO | Adjustable Speed Drives | 0.80 | - | - | - | - | - | - | - | - | - | - | - | 0.80 |
| | Water Chillers | 1.09 | - | 0.19 | 0.67 | - | - | - | - | - | - | 0.35 | - | 0.38 |
| | Cooling Towers | - | - | 0.20 | 0.27 | - | - | 0.91 | - | - | - | 0.18 | - | 0.39 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Retrofit Efficiency Options Program Total | | 0.84 | - | 0.20 | 0.54 | - | - | 0.91 | - | - | - | 0.30 | - | 0.48 |
| APO | Water Chillers | 0.51 | - | - | - | - | - | 0.33 | - | - | 0.91 | 0.91 | - | 0.68 |
| | Customized EMS | 0.13 | - | 0.91 | - | - | - | - | - | - | 0.91 | - | - | 0.62 |
| | Customized Controls | 1.40 | - | - | - | - | - | 0.85 | - | - | - | - | - | 1.30 |
| | Convert To VAV | 0.91 | 0.96 | - | - | - | - | - | - | - | - | - | - | 0.91 |
| | Other Customized Equip | 0.91 | - | 0.92 | - | - | - | - | 0.96 | - | - | - | - | 0.93 |
| | Other HVAC Technologies | 1.21 | - | - | - | - | - | - | - | - | - | 0.91 | - | 0.96 |
| Advanced Performance Options Program Total | | 0.71 | 0.96 | 0.92 | - | - | - | 0.30 | 0.96 | - | 0.91 | 0.91 | - | 0.77 |
| **Total** | | 0.75 | 0.77 | 0.73 | 0.52 | 0.22 | 0.73 | 0.34 | 0.97 | 0.56 | 0.94 | 0.89 | 1.06 | **0.76** |

### *Attachment 3-10*
### *Commercial HVAC Ex Ante Gross Demand Impacts*
### *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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 67 | 26 | 30 | 10 | - | 23 | 23 | 1 | - | 11 | 36 | 3 | 230 |
| | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Package Terminal A/C | 2 | - | - | 0.3 | - | 6 | - | 32 | - | - | - | - | 40 |
| | Set-Back Thermostat | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Reflective Window Film | 18 | - | 1 | - | - | 0.4 | 12 | - | 2 | 2 | 0.5 | - | 36 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 14 | - | 14 |
| | Other HVAC Technologies | - | - | - | - | 17 | - | - | - | - | - | - | - | 17 |
| Retrofit Express Program Total | | 86 | 26 | 30 | 11 | 17 | 29 | 35 | 33 | 2 | 13 | 51 | 3 | 337 |
| REO | Adjustable Speed Drives | 5 | - | - | - | - | - | - | - | - | - | - | - | 5 |
| | Water Chillers | 27 | - | 102 | 66 | - | - | - | - | - | - | 68 | - | 263 |
| | Cooling Towers | - | - | 31 | 17 | - | - | 32 | - | - | - | 10 | - | 89 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Retrofit Efficiency Options Program Total | | 32 | 0 | 133 | 83 | 0 | 0 | 32 | 0 | 0 | 0 | 78 | 0 | 357 |
| APO | Water Chillers | 705 | - | - | - | - | - | 192 | - | - | 99 | 542 | - | 1,538 |
| | Customized EMS | 62 | - | - | - | - | - | 66 | - | - | - | - | - | 128 |
| | Customized Controls | 3 | - | - | - | - | - | - | - | - | - | - | - | 3 |
| | Convert To VAV | 65 | 22 | - | - | - | - | - | - | - | - | - | - | 87 |
| | Other Customized Equip | 117 | - | 300 | - | - | - | - | 75 | - | - | - | - | 492 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 216 | - | 216 |
| Advanced Performance Options Program Total | | 952 | 22 | 300 | 0 | 0 | 0 | 258 | 75 | 0 | 99 | 758 | 0 | 2,464 |
| **Total** | | 1,071 | 48 | 463 | 94 | 17 | 29 | 325 | 108 | 2 | 112 | 887 | 3 | **3,159** |

## *Attachment 3-11*
## *Commercial HVAC Ex Ante Net Demand Impacts*
## *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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 51 | 20 | 23 | 8 | - | 18 | 18 | 1 | - | 8 | 28 | 2 | 177 |
| | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Package Terminal A/C | 2 | - | - | 0.2 | - | 4 | - | 25 | - | - | - | - | 31 |
| | Set-Back Thermostat | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Reflective Window Film | 14 | - | 0.4 | - | - | 0.3 | 9 | - | 2 | 2 | 0.4 | - | 27 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 11 | - | 11 |
| | Other HVAC Technologies | - | - | - | - | 13 | - | - | - | - | - | - | - | 13 |
| Retrofit Express Program Total | | 67 | 20 | 23 | 8 | 13 | 22 | 27 | 25 | 2 | 10 | 39 | 2 | 260 |
| REO | Adjustable Speed Drives | 4 | - | - | - | - | - | - | - | - | - | - | - | 4 |
| | Water Chillers | 20 | - | 76 | 50 | - | - | - | - | - | - | 51 | - | 197 |
| | Cooling Towers | - | - | 23 | 13 | - | - | 24 | - | - | - | 7 | - | 67 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Retrofit Efficiency Options Program Total | | 24 | 0 | 100 | 62 | 0 | 0 | 24 | 0 | 0 | 0 | 58 | 0 | 268 |
| APO | Water Chillers | 529 | - | - | - | - | - | 144 | - | - | 74 | 407 | - | 1,154 |
| | Customized EMS | 47 | - | - | - | - | - | 50 | - | - | - | - | - | 96 |
| | Customized Controls | 2 | - | - | - | - | - | - | - | - | - | - | - | 2 |
| | Convert To VAV | 49 | 17 | - | - | - | - | - | - | - | - | - | - | 65 |
| | Other Customized Equip | 88 | - | 225 | - | - | - | - | 56 | - | - | - | - | 369 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 162 | - | 162 |
| Advanced Performance Options Program Total | | 714 | 17 | 225 | 0 | 0 | 0 | 194 | 56 | 0 | 74 | 569 | 0 | 1,848 |
| **Total** | | 805 | 36 | 348 | 70 | 13 | 22 | 244 | 82 | 2 | 84 | 666 | 2 | **2,376** |

### *Attachment 3-12*
### *Commercial HVAC Unadjusted Engineering Demand Impacts*
### *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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 57.9 | 16 | 9 | 11 | - | 18 | 20 | 1 | - | 11 | 27 | 3 | 174 |
| | Adjustable Speed Drives | 69 | - | - | - | - | - | - | - | - | 36 | 15 | - | 119 |
| | Package Terminal A/C | 2 | - | - | 1 | - | 3 | - | 29 | - | - | - | - | 34 |
| | Set-Back Thermostat | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Reflective Window Film | 23 | - | 0.3 | - | - | 0.3 | 16 | - | 2 | 1 | 1 | - | 44 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 14 | - | 14 |
| | Other HVAC Technologies | - | - | - | - | 18 | - | - | - | - | - | - | - | 18 |
| Retrofit Express Program Total | | 151 | 16 | 9 | 12 | 18 | 21 | 36 | 30 | 2 | 48 | 56 | 3 | 403 |
| REO | Adjustable Speed Drives | 76 | - | - | - | - | - | - | - | - | - | - | - | 76 |
| | Water Chillers | 36 | - | 80 | 96 | - | - | - | - | - | - | 48 | - | 260 |
| | Cooling Towers | - | - | 43 | 22 | - | - | 32 | - | - | - | 11 | - | 106 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Retrofit Efficiency Options Program Total | | 112 | 0 | 123 | 117 | 0 | 0 | 32 | 0 | 0 | 0 | 59 | 0 | 442 |
| APO | Water Chillers | 864 | - | - | - | - | - | 200 | - | - | 99 | 542 | - | 1,705 |
| | Customized EMS | 99 | - | - | - | - | - | - | - | - | - | - | - | 99 |
| | Customized Controls | 73 | - | - | - | - | - | - | - | - | - | - | - | 73 |
| | Convert To VAV | 65 | 35 | - | - | - | - | - | - | - | - | - | - | 100 |
| | Other Customized Equip | 117 | - | 300 | - | - | - | - | 83 | - | - | - | - | 500 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 216 | - | 216 |
| Advanced Performance Options Program Total | | 1,217 | 35 | 300 | 0 | 0 | 0 | 200 | 83 | 0 | 99 | 758 | 0 | 2,692 |
| **Total** | | 1,481 | 51 | 431 | 129 | 18 | 21 | 268 | 113 | 2 | 147 | 873 | 3 | **3,538** |

*Attachment 3-13*
***Commercial HVAC Ex Post Gross Demand Impacts***
***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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 58 | 16 | 9 | 11 | - | 18 | 20 | 1 | - | 11 | 27 | 3 | 174 |
| | Adjustable Speed Drives | 69 | - | - | - | - | - | - | - | - | 36 | 15 | - | 119 |
| | Package Terminal A/C | 2 | - | - | 1 | - | 3 | - | 29 | - | - | - | - | 34 |
| | Set-Back Thermostat | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Reflective Window Film | 23 | - | 0.3 | - | - | 0.3 | 16 | - | 2 | 1 | 1 | - | 44 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 14 | - | 14 |
| | Other HVAC Technologies | - | - | - | - | 18 | - | - | - | - | - | - | - | 18 |
| Retrofit Express Program Total | | 151 | 16 | 9 | 12 | 18 | 21 | 36 | 30 | 2 | 48 | 56 | 3 | 403 |
| REO | Adjustable Speed Drives | 76 | - | - | - | - | - | - | - | - | - | - | - | 76 |
| | Water Chillers | 36 | - | 80 | 96 | - | - | - | - | - | - | 48 | - | 260 |
| | Cooling Towers | - | - | 43 | 22 | - | - | 32 | - | - | - | 11 | - | 106 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Retrofit Efficiency Options Program Total | | 112 | 0 | 123 | 117 | 0 | 0 | 32 | 0 | 0 | 0 | 59 | 0 | 442 |
| APO | Water Chillers | 864 | - | - | - | - | - | 200 | - | - | 99 | 542 | - | 1,705 |
| | Customized EMS | 99 | - | - | - | - | - | - | - | - | - | - | - | 99 |
| | Customized Controls | 73 | - | - | - | - | - | - | - | - | - | - | - | 73 |
| | Convert To VAV | 65 | 35 | - | - | - | - | - | - | - | - | - | - | 100 |
| | Other Customized Equip | 117 | - | 300 | - | - | - | - | 83 | - | - | - | - | 500 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 216 | - | 216 |
| Advanced Performance Options Program Total | | 1,217 | 35 | 300 | 0 | 0 | 0 | 200 | 83 | 0 | 99 | 758 | 0 | 2,692 |
| **Total** | | 1,481 | 51 | 431 | 129 | 18 | 21 | 268 | 113 | 2 | 147 | 873 | 3 | **3,538** |

## *Attachment 3-14*
## *Commercial HVAC Gross Demand Impact Realization Rates*
## *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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 0.87 | 0.64 | 0.29 | 1.11 | - | 0.77 | 0.86 | 0.87 | - | 0.98 | 0.74 | 1.01 | 0.76 |
| | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Package Terminal A/C | 1.03 | - | - | 1.81 | - | 0.50 | - | 0.90 | - | - | - | - | 0.86 |
| | Set-Back Thermostat | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Reflective Window Film | 1.27 | - | 0.58 | - | - | 0.72 | 1.37 | - | 1.01 | 0.71 | 1.13 | - | 1.23 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 1.00 | - | 1.00 |
| | Other HVAC Technologies | - | - | - | - | 1.03 | - | - | - | - | - | - | - | 1.03 |
| Retrofit Express Program Total | | 1.75 | 0.64 | 0.30 | 1.13 | 1.03 | 0.71 | 1.03 | 0.90 | 1.01 | 3.69 | 1.10 | 1.01 | 1.20 |
| REO | Adjustable Speed Drives | 14.38 | - | - | - | - | - | - | - | - | - | - | - | 14.38 |
| | Water Chillers | 1.33 | - | 0.78 | 1.45 | - | - | - | - | - | - | 0.71 | - | 0.99 |
| | Cooling Towers | - | - | 1.39 | 1.27 | - | - | 1.00 | - | - | - | 1.08 | - | 1.19 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Retrofit Efficiency Options Program Total | | 3.46 | - | 0.92 | 1.41 | - | - | 1.00 | - | - | - | 0.76 | - | 1.24 |
| APO | Water Chillers | 1.23 | - | - | - | - | - | 1.04 | - | - | 1.00 | 1.00 | - | 1.11 |
| | Customized EMS | 1.59 | - | - | - | - | - | - | - | - | - | - | - | 0.77 |
| | Customized Controls | 24.40 | - | - | - | - | - | - | - | - | - | - | - | 24.40 |
| | Convert To VAV | 1.00 | 1.58 | - | - | - | - | - | - | - | - | - | - | 1.15 |
| | Other Customized Equip | 1.00 | - | 1.00 | - | - | - | - | 1.10 | - | - | - | - | 1.02 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 1.00 | - | 1.00 |
| Advanced Performance Options Program Total | | 1.28 | 1.58 | 1.00 | - | - | - | 0.78 | 1.10 | - | 1.00 | 1.00 | - | 1.09 |
| **Total** | | 1.38 | 1.08 | 0.93 | 1.38 | 1.03 | 0.71 | 0.83 | 1.04 | 1.01 | 1.31 | 0.98 | 1.01 | **1.12** |

## *Attachment 3-15*
## *Commercial HVAC Net-to-Gross Adjustments for Demand Impacts*
## *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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 |
| | Adjustable Speed Drives | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 |
| | Package Terminal A/C | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 |
| | Set-Back Thermostat | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |
| | Reflective Window Film | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 |
| | Water Chillers | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Other HVAC Technologies | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| Retrofit Express Program Total | | 0.63 | 0.59 | 0.58 | 0.61 | 0.14 | 0.65 | 0.49 | 1.02 | 0.36 | 0.69 | 0.70 | 0.59 | 0.64 |
| REO | Adjustable Speed Drives | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 |
| | Water Chillers | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Cooling Towers | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 2.20 |
| | High Efficiency Gas Boilers | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| Retrofit Efficiency Options Program Total | | 0.79 | [illegible] | 0.90 | 0.90 | [illegible] | [illegible] | 0.90 | [illegible] | [illegible] | [illegible] | 0.90 | [illegible] | 0.87 |
| APO | Water Chillers | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Customized EMS | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Customized Controls | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Convert To VAV | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Other Customized Equip | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Other HVAC Technologies | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| Advanced Performance Options Program Total | | 0.90 | 0.90 | 0.90 | [illegible] | [illegible] | [illegible] | 0.90 | 0.90 | [illegible] | 0.90 | 0.90 | [illegible] | 0.90 |
| **Total** | | 0.87 | 0.80 | 0.90 | 0.87 | 0.14 | 0.65 | 0.85 | 0.93 | 0.36 | 0.83 | 0.89 | 0.59 | 0.87 |

*Attachment 3-16*
***Commercial HVAC Ex Post Net Demand Impacts***
***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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 34 | 10 | 5 | 7 | - | 10 | 12 | 1 | - | 6 | 16 | 2 | 102 |
| | Adjustable Speed Drives | 50 | - | - | - | - | - | - | - | - | 26 | 11 | - | 87 |
| | Package Terminal A/C | 2 | - | - | 1 | - | 3 | - | 30 | - | - | - | - | 35 |
| | Set-Back Thermostat | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Reflective Window Film | 8 | - | 0 | - | - | 0 | 6 | - | 1 | 1 | 0 | - | 16 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 13 | - | 13 |
| | Other HVAC Technologies | - | - | - | - | 3 | - | - | - | - | - | - | - | 3 |
| Retrofit Express Program Total | | 95 | 10 | 5 | 7 | 3 | 13 | 18 | 30 | 1 | 33 | 40 | 2 | 256 |
| REO | Adjustable Speed Drives | 56 | - | - | - | - | - | - | - | - | - | - | - | 56 |
| | Water Chillers | 33 | - | 72 | 86 | - | - | - | - | - | - | 43 | - | 234 |
| | Cooling Towers | - | - | 38 | 19 | - | - | 28 | - | - | - | 10 | - | 96 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| Retrofit Efficiency Options Program Total | | 88 | 0 | 110 | 106 | 0 | 0 | 28 | 0 | 0 | 0 | 53 | 0 | 386 |
| APO | Water Chillers | 779 | - | - | - | - | - | 180 | - | - | 89 | 489 | - | 1,538 |
| | Customized EMS | 89 | - | - | - | - | - | - | - | - | - | - | - | 89 |
| | Customized Controls | 66 | - | - | - | - | - | - | - | - | - | - | - | 66 |
| | Convert To VAV | 59 | 31 | - | - | - | - | - | - | - | - | - | - | 90 |
| | Other Customized Equip | 106 | - | 271 | - | - | - | - | 75 | - | - | - | - | 451 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 195 | - | 195 |
| Advanced Performance Options Program Total | | 1,098 | 31 | 271 | 0 | 0 | 0 | 180 | 75 | 0 | 89 | 684 | 0 | 2,429 |
| **Total** | | 1,281 | 41 | 386 | 113 | 3 | 13 | 227 | 105 | 1 | 122 | 776 | 2 | **3,071** |

## *Attachment 3-17*
## *Commercial HVAC Net Demand Impact Realization Rates*
## *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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 0.66 | 0.49 | 0.22 | 0.85 | - | 0.59 | 0.66 | 0.66 | - | 0.75 | 0.57 | 0.77 | 0.58 |
| | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Package Terminal A/C | 1.39 | - | - | 2.44 | - | 0.67 | - | 1.22 | - | - | - | - | 1.16 |
| | Set-Back Thermostat | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Reflective Window Film | 0.59 | - | 0.27 | - | - | 0.34 | 0.64 | - | 0.47 | 0.33 | 0.53 | - | 0.58 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | 1.17 | - | 1.17 |
| | Other HVAC Technologies | - | - | - | - | 0.19 | - | - | - | - | - | - | - | 0.19 |
| Retrofit Express Program Total | | 1.42 | 0.49 | 0.22 | 0.89 | 0.19 | 0.60 | 0.65 | 1.20 | 0.47 | 3.31 | 1.01 | 0.77 | 0.99 |
| REO | Adjustable Speed Drives | 14.05 | - | - | - | - | - | - | - | - | - | - | - | 14.05 |
| | Water Chillers | 1.60 | - | 0.94 | 1.74 | - | - | - | - | - | - | 0.86 | - | 1.19 |
| | Cooling Towers | - | - | 1.67 | 1.53 | - | - | 1.20 | - | - | - | 1.30 | - | 1.43 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Retrofit Efficiency Options Program Total | | 3.63 | - | 1.11 | 1.70 | - | - | 1.20 | - | - | - | 0.91 | - | 1.44 |
| APO | Water Chillers | 1.47 | - | - | - | - | - | 1.25 | - | - | 1.20 | 1.20 | - | 1.33 |
| | Customized EMS | 1.91 | - | - | - | - | - | - | - | - | - | - | - | 0.93 |
| | Customized Controls | 29.35 | - | - | - | - | - | - | - | - | - | - | - | 29.35 |
| | Convert To VAV | 1.20 | 1.90 | - | - | - | - | - | - | - | - | - | - | 1.38 |
| | Other Customized Equip | 1.20 | - | 1.20 | - | - | - | - | 1.33 | - | - | - | - | 1.22 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 1.20 | - | 1.20 |
| Advanced Performance Options Program Total | | 1.54 | 1.90 | 1.20 | - | - | - | 0.93 | 1.33 | - | 1.20 | 1.20 | - | 1.31 |
| **Total** | | 1.59 | 1.13 | 1.11 | 1.60 | 0.19 | 0.60 | 0.93 | 1.29 | 0.47 | 1.45 | 1.17 | 0.77 | **1.29** |

*Attachment 3-18*
*Commercial HVAC Ex Ante Gross Therm Impacts*
*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. | 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 |
| REO | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Cooling Towers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | 2,507 | - | - | 2,507 |
| Retrofit Efficiency Options Program Total | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,507 | 0 | 0 | 2,507 |
| APO | Water Chillers | - | - | - | - | - | - | - | - | - | - | 89,512 | - | 89,512 |
| | Customized EMS | - | - | 26,768 | - | - | - | 79,821 | - | - | - | - | - | 106,589 |
| | Customized Controls | 53,039 | - | - | - | - | - | 9,819 | - | - | - | - | - | 62,858 |
| | Convert To VAV | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Other Customized Equip | 77,029 | - | 183,758 | - | - | - | - | - | - | - | - | - | 260,787 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 53,534 | - | 53,534 |
| Advanced Performance Options Program Total | | 130,068 | 0 | 210,526 | 0 | 0 | 0 | 89,640 | 0 | 0 | 0 | 143,046 | 0 | 573,280 |
| **Total** | | 130,068 | 0 | 210,526 | 0 | 0 | 0 | 89,640 | 0 | 0 | 2,507 | 143,046 | 0 | **575,787** |

## *Attachment 3-19*
## *Commercial HVAC Ex Ante Net Therm Impacts*
## *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. | 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 |
| REO | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Cooling Towers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | 1,880 | - | - | 1,880 |
| Retrofit Efficiency Options Program Total | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,880 | 0 | 0 | 1,880 |
| APO | Water Chillers | - | - | - | - | - | - | - | - | - | - | 67,134 | - | 67,134 |
| | Customized EMS | - | - | 20,076 | - | - | - | 59,866 | - | - | - | - | - | 79,942 |
| | Customized Controls | 39,779 | - | - | - | - | - | 7,364 | - | - | - | - | - | 47,144 |
| | Convert To VAV | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Other Customized Equip | 57,772 | - | 137,819 | - | - | - | - | - | - | - | - | - | 195,590 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 40,151 | - | 40,151 |
| Advanced Performance Options Program Total | | 97,551 | 0 | 157,895 | 0 | 0 | 0 | 67,230 | 0 | 0 | 0 | 107,285 | 0 | 429,960 |
| **Total** | | 97,551 | 0 | 157,895 | 0 | 0 | 0 | 67,230 | 0 | 0 | 1,880 | 107,285 | 0 | **431,840** |

*Attachment 3-20*
*Commercial HVAC Unadjusted Engineering Therm Impacts*
*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. | 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 |
| REO | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Cooling Towers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | 2,507 | - | - | 2,507 |
| Retrofit Efficiency Options Program Total | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,507 | 0 | 0 | 2,507 |
| APO | Water Chillers | - | - | - | - | - | - | - | - | - | - | 89,512 | - | 89,512 |
| | Customized EMS | - | - | 26,768 | - | - | - | - | - | - | - | - | - | 26,768 |
| | Customized Controls | 48,028 | - | - | - | - | - | 8,545 | - | - | - | - | - | 56,573 |
| | Convert To VAV | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Other Customized Equip | 77,029 | - | 183,758 | - | - | - | - | - | - | - | - | - | 260,787 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 53,534 | - | 53,534 |
| Advanced Performance Options Program Total | | 125,057 | 0 | 210,526 | 0 | 0 | 0 | 8,545 | 0 | 0 | 0 | 143,046 | 0 | 487,174 |
| **Total** | | 125,057 | 0 | 210,526 | 0 | 0 | 0 | 8,545 | 0 | 0 | 2,507 | 143,046 | 0 | **489,681** |

## *Attachment 3-21*
## *Commercial HVAC Ex Post Gross Therm Impacts*
## *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. | 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 |
| REO | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Cooling Towers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | 2,507 | - | - | 2,507 |
| Retrofit Efficiency Options Program Total | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,507 | 0 | 0 | 2,507 |
| APO | Water Chillers | - | - | - | - | - | - | - | - | - | - | 89,512 | - | 89,512 |
| | Customized EMS | - | - | 26,768 | - | - | - | - | - | - | - | - | - | 26,768 |
| | Customized Controls | 48,028 | - | - | - | - | - | 8,545 | - | - | - | - | - | 56,573 |
| | Convert To VAV | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Other Customized Equip | 77,029 | - | 183,758 | - | - | - | - | - | - | - | - | - | 260,787 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 53,534 | - | 53,534 |
| Advanced Performance Options Program Total | | 125,057 | 0 | 210,526 | 0 | 0 | 0 | 8,545 | 0 | 0 | 0 | 143,046 | 0 | 487,174 |
| **Total** | | 125,057 | 0 | 210,526 | 0 | 0 | 0 | 8,545 | 0 | 0 | 2,507 | 143,046 | 0 | **489,681** |

*Attachment 3-22*

***Commercial HVAC Gross Therm Impact Realization Rates***

***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. | 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 | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| REO | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Cooling Towers | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | 1.00 | - | - | 1.00 |
| Retrofit Efficiency Options Program Total | | - | - | - | - | - | - | - | - | - | 1.00 | - | - | 1.00 |
| APO | Water Chillers | - | - | - | - | - | - | - | - | - | - | 1.00 | - | 1.00 |
| | Customized EMS | - | - | 1.00 | - | - | - | - | - | - | - | - | - | 0.25 |
| | Customized Controls | 0.91 | - | - | - | - | - | 0.87 | - | - | - | - | - | 0.90 |
| | Convert To VAV | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Other Customized Equip | 1.00 | - | 1.00 | - | - | - | - | - | - | - | - | - | 1.00 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 1.00 | - | 1.00 |
| Advanced Performance Options Program Total | | 0.96 | - | 1.00 | - | - | - | 0.10 | - | - | - | 1.00 | - | 0.85 |
| **Total** | | 0.96 | - | 1.00 | - | - | - | 0.10 | - | - | 1.00 | 1.00 | - | **0.85** |

*Attachment 3-23*

***Commercial HVAC Net-to-Gross Adjustments for Therm Impacts***

***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. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Retrofit Express | Central A/C | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | - |
| | Adjustable Speed Drives | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | [illegible] |
| | Package Terminal A/C | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | [illegible] |
| | Set-Back Thermostat | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | [illegible] |
| | Reflective Window Film | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | [illegible] |
| | Water Chillers | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | [illegible] |
| | Other HVAC Technologies | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | [illegible] |
| Retrofit Express Program Total | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| REO | Adjustable Speed Drives | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | 0.73 | [illegible] |
| | Water Chillers | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | [illegible] |
| | Cooling Towers | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | [illegible] |
| | High Efficiency Gas Boilers | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| Retrofit Efficiency Options Program Total | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 0.90 | [illegible] | [illegible] | 0.90 |
| APO | Water Chillers | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Customized EMS | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Customized Controls | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Convert To VAV | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | [illegible] |
| | Other Customized Equip | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| | Other HVAC Technologies | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| Advanced Performance Options Program Total | | 0.90 | [illegible] | 0.90 | [illegible] | [illegible] | [illegible] | 0.90 | [illegible] | [illegible] | [illegible] | 0.90 | [illegible] | 0.90 |
| **Total** | | 0.90 | [illegible] | 0.90 | [illegible] | [illegible] | [illegible] | 0.90 | [illegible] | [illegible] | 0.90 | 0.90 | [illegible] | 0.90 |

*Attachment 3-24*
***Commercial HVAC Ex Post Net Therm Impacts***
***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. | 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 |
| REO | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Cooling Towers | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | 2,261 | - | - | 2,261 |
| Retrofit Efficiency Options Program Total | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,261 | 0 | 0 | 2,261 |
| APO | Water Chillers | - | - | - | - | - | - | - | - | - | - | 80,741 | - | 80,741 |
| | Customized EMS | - | - | 24,145 | - | - | - | - | - | - | - | - | - | 24,145 |
| | Customized Controls | 43,322 | - | - | - | - | - | 7,707 | - | - | - | - | - | 51,030 |
| | Convert To VAV | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Other Customized Equip | 69,482 | - | 165,753 | - | - | - | - | - | - | - | - | - | 235,234 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 48,289 | - | 48,289 |
| Advanced Performance Options Program Total | | 112,804 | 0 | 189,898 | 0 | 0 | 0 | 7,707 | 0 | 0 | 0 | 129,030 | 0 | 439,440 |
| **Total** | | 112,804 | 0 | 189,898 | 0 | 0 | 0 | 7,707 | 0 | 0 | 2,261 | 129,030 | 0 | **441,701** |

## *Attachment 3-25*
## *Commercial HVAC Net Therm Impact Realization Rates*
## *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. | 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 | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| REO | Adjustable Speed Drives | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Water Chillers | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Cooling Towers | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | High Efficiency Gas Boilers | - | - | - | - | - | - | - | - | - | 1.20 | - | - | 1.20 |
| Retrofit Efficiency Options Program Total | | - | - | - | - | - | - | - | - | - | 1.20 | - | - | 1.20 |
| APO | Water Chillers | - | - | - | - | - | - | - | - | - | - | 1.20 | - | 1.20 |
| | Customized EMS | - | - | 1.20 | - | - | - | - | - | - | - | - | - | 0.30 |
| | Customized Controls | 1.09 | - | - | - | - | - | 1.05 | - | - | - | - | - | 1.08 |
| | Convert To VAV | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Other Customized Equip | 1.20 | - | 1.20 | - | - | - | - | - | - | - | - | - | 1.20 |
| | Other HVAC Technologies | - | - | - | - | - | - | - | - | - | - | 1.20 | - | 1.20 |
| Advanced Performance Options Program Total | | 1.16 | - | 1.20 | - | - | - | 0.11 | - | - | - | 1.20 | - | 1.02 |
| **Total** | | 1.16 | - | 1.20 | - | - | - | 0.11 | - | - | 1.20 | 1.20 | - | **1.02** |

# *Attachment 3-26*
# *Commercial HVAC Measures*
# *Measure Code Key*

| Program and Technology Group \ Business Type | PG&E Measure Classification | |
|---|---|---|
| | Measure Code | Action Code |
| Retrofit Express Program | | |
| Central A/C | S2, S160-S163 | |
| Adjustable Speed Drives | S22 | |
| Package Terminal A/C | S6 | |
| Programmable Thermostat | S17, S18 | |
| Reflective Window Film | S20 | |
| Water Chiller | S12, S13 | |
| Other HVAC Technologies | S21 | |
| Retrofit Efficiency Options Program | | |
| Adjustable Speed Drives | S89, S90, S92, S93 | |
| Water Chillers | S97, S98, S99 | |
| Cooling Tower | S94, S96 | |
| High Efficiency Gas Chillers | S100 | |
| Advanced Performance Options Program | | |
| Water Chillers | S0 | 232 |
| Customized EMS | S0 | 204 |
| Customized Controls | S0 | 201 |
| Convert to VAV | S0 | 230 |
| Other Customized Equipment | S0 | 299 |
| Other HVAC Technologies | S0 | 234, 271 |

*Attachment 3-27*
*Time-of-Use Impact Distribution by Costing Period*

| PG&E Cost Period | Time-of-Use Impact Distribution | |
|---|---|---|
| | kW Adjustment Factor | kWh Adjustment Factor |
| Summer On-Peak:<br>May 1 to Oct. 31<br>12:00 PM - 6:00 PM Weekdays | 1.0000 | 0.1320 |
| Summer Partial Peak:<br>May 1 to Oct. 31<br>8:30 AM - 12:00 PM &<br>6:00 PM - 9:30 PM Weekdays | 0.9020 | 0.1320 |
| Summer Off-Peak:<br>May to Oct. 31<br>9:30 PM - 8:30 AM | 0.5320 | 0.2990 |
| Winter Partial Peak:<br>Nov. 1 to April 31<br>8:30 AM - 9:30 PM Weekdays | 0.5150 | 0.2620 |
| Winter Off-Peak:<br>Nov. 1 to April 31<br>9:30 PM - 8:30 AM Other | 0.4300 | 0.1750 |

*Attachment 4*

*Protocol Tables 6 and 7*

## *PROTOCOL TABLES 6 AND 7*

### *PRE-1998 COMMERCIAL EEI PROGRAM CARRY-OVER EVALUATION OF HVAC TECHNOLOGIES*

### *PG&E STUDY ID #404B*

This Attachment presents Tables 6 and 7 for the above referenced study as required under the "Protocols and Procedures for the Verification of Cost, Benefits, and Shareholder Earnings from Demand Side Management Programs" (the Protocols), as adopted by the California Public Utility Commission (CPUC) Decision 93-05-063, Revised March 1998 Pursuant to Decisions 94-05-063, 94-10-059, 94-12-021, 95-12-054, 96-12-079, and 98-03-063.

**Table 6 Assumptions**

In some instances, interpretation of the Protocols allows for a variety of results to be presented. For HVAC technologies, the interpretation of these terms are:

- Items 1.A, 1.B, 2.C, 3.C: The change model of estimates did not require an evaluation of base usage for these technologies.
- Item 2.B: The per-unit gross and net impacts required by the Protocols specify one term in the denominator, square footage. The interpretation of this term is:
  - Square footage estimates of the conditioned area were derived using survey responses for total area affected by the retrofit.
- Items 6 and 7: The number of measures reported are the purchased number in the MDSS. As such, they reflect a variety of units of measure, including square feet, number of units, feet of window film, number of thermostats, etc.

The Table 7 synopsis of analytical methods applied follows Items 1 through 7 of Protocol Table 6.

## *Protocol Table 6*
## *Items 1-5*
## *PG&E HVAC Study ID #404B*

| Item Number | Table Item: Description | Estimate | Relative Precision: 90% Confidence | Relative Precision: 80% Confidence |
|---|---|---|---|---|
| 1.A† | Pre-installation usage, Base usage, and Base usage per designated unit* of measurement. | N/A | N/A | N/A |
| 1.B† | Impact Year usage, Impact year usage per designated unit* of measurement. | N/A | N/A | N/A |
| 2.A | Gross Peak kW (Demand) Impacts | 3,538 | 95% | 74% |
| | Gross kWh (Energy) Impacts | 13,659,972 | 94% | 73% |
| | Gross thm (Therm) Impacts | 489,681 | 95% | 74% |
| | Net Peak kW (Demand) Impacts | 3,071 | 96% | 75% |
| | Net kWh (Energy) Impacts | 11,865,436 | 95% | 74% |
| | Net thm (Therm) Impacts | 441,701 | 96% | 75% |
| 2.B | Per designated unit* Gross Demand (kW) Impacts | 0.00018 | 95% | 74% |
| | Per designated unit* Gross Energy (kWh) Impacts | 0.71097 | 94% | 73% |
| | Per designated unit Gross Therm Impacts | 0.02549 | 95% | 74% |
| | Per designated unit* Net Demand (kW) Impacts | 0.00016 | 96% | 75% |
| | Per designated unit* Net Energy (kWh) Impacts | 0.61757 | 95% | 74% |
| | Per designated unit Net Therm Impacts | 0.02299 | 96% | 75% |
| 2.C† | Percent change in usage (relative to base usage) of the participant group and comparison group. | N/A | N/A | N/A |
| 2.D | Gross Demand Realization Rate | 1.120 | 95% | 74% |
| | Gross Energy Realization Rate | 0.661 | 94% | 73% |
| | Gross Therm Realization Rate | 0.850 | 95% | 74% |
| | Net Demand Realization Rate | 1.293 | 96% | 75% |
| | Net Energy Realization Rate | 0.764 | 95% | 74% |
| | Net Therm Realization Rate | 1.023 | 96% | 75% |
| 3.A | Net-to-Gross ratio based on Avg. Load Impacts | 0.869 | 15% | 12% |
| 3.B | Net-to-Gross ratio based on Avg. Load Impacts per designated unit* of measurement. | 0.869 | 15% | 12% |
| 3.C† | Net-to-Gross ratio based on Avg. Load Impacts as a percent change from base usage | N/A | N/A | N/A |
| 4.A | Pre-installation Avg. (mean) Sq. Foot (participant group) | 140,474 | 29.7% | 23.1% |
| | Pre-installation Avg. (mean) Sq. Foot (comparison group) | 66,642 | 16.2% | 12.6% |
| | Pre-installation Avg. Hours of Operation (participant group) | | | |
| | Pre-installation Avg. Hours of Operation (comparison group) | | | |
| 4.B | Post-installation Avg. (mean) Sq. Foot (participant group) | 141,288 | 29.5% | 23.0% |
| | Post-installation Avg. (mean) Sq. Foot (comparison group) | 67,031 | 16.2% | 12.6% |
| | Post-installation Avg. Hours of Operation (participant group) | | | |
| | Post-installation Avg. Hours of Operation (comparison group) | | | |

† The change model estimates of impact did not require an evaluation of base usage

* The per designated unit used was Sq. Ft.

Shaded cells were not evaluated because per designated unit calculations did not use these estimates.

*Protocol Table 6*
*Item 6: HVAC Measure Count Data*
*PG&E Study ID #404B*

| Program and Technology Group Description | Number of Measures Paid in 1997: All Participants (Item 6.B) | Participant Sample (Item 6.A) | Comparison Group (Item 6.C) |
|---|---|---|---|
| **Retrofit Express Program** | | | |
| Central A/C | 149 | 113 | 1,444 |
| Adjustable Speed Drives | 25 | 15 | 0 |
| Package Terminal A/C | 188 | 88 | 137 |
| Set-Back Thermostat | 58 | 58 | 23 |
| Reflective Window Film | 15,439 | 7,854 | 0 |
| Water Chillers | 2 | 2 | 25 |
| Other HVAC Technologies | 6 | 6 | 163 |
| **Total for Retrofit Express:** | **15,867** | **8,136** | **1,792** |
| **Retrofit Efficiency Options Program** | | | |
| Adjustable Speed Drives | 3 | 1 | |
| Water Chillers | 5 | 3 | |
| Cooling Towers | 4 | 2 | |
| High Efficiency Gas Boilers | 1 | 0 | |
| **Total for REO:** | **13** | **6** | **0** |
| **Advanced Performance Options Program** | | | |
| Water Chillers | 11 | 7 | |
| Customized EMS | 7 | 2 | |
| Customized Controls | 5 | 4 | |
| Convert to VAV | 2 | 0 | |
| Other Customized Equipment | 5 | 3 | |
| Other HVAC Technologies | 2 | 2 | |
| **Total for APO:** | **32** | **18** | **0** |
| **TOTAL:** | **15,912** | **8,160** | **1,792** |

## *Protocol Table 6*
## *Item 7.A: HVAC Market Segment Data by Business Type*
## *PG&E Study ID # 404B*

| Business Type | HVAC # of Part. | HVAC % of Part. |
|---|---|---|
| Office | 54 | 39% |
| Retail | 5 | 4% |
| Col/Univ | 8 | 6% |
| School | 7 | 5% |
| Grocery | 1 | 1% |
| Restaurant | 7 | 5% |
| Health Care/Hospital | 13 | 9% |
| Hotel/Motel | 8 | 6% |
| Warehouse | 2 | 1% |
| Personal Service | 11 | 8% |
| Community Service | 18 | 13% |
| Misc. Commercial | 3 | 2% |
| **TOTAL:** | **137** | **100%** |

***Protocol Table 6***
***Item 7.B: HVAC Market Segment Data***
***by 3-Digit SIC Code***
***PG&E Study ID # 404B***

| | HVAC | |
|---|---|---|
| Industry (3-Digit SIC Code) | # of Part. | % of Part. |
| 652 | 34 | 24.8% |
| 701 | 8 | 5.8% |
| 822 | 8 | 5.8% |
| 581 | 7 | 5.1% |
| 821 | 7 | 5.1% |
| 737 | 6 | 4.4% |
| 806 | 6 | 4.4% |
| 922 | 5 | 3.6% |
| 866 | 4 | 2.9% |
| 650 | 3 | 2.2% |
| 799 | 3 | 2.2% |
| 921 | 3 | 2.2% |
| 431 | 2 | 1.5% |
| 602 | 2 | 1.5% |
| 631 | 2 | 1.5% |
| 738 | 2 | 1.5% |
| 754 | 2 | 1.5% |
| 804 | 2 | 1.5% |
| 805 | 2 | 1.5% |
| 809 | 2 | 1.5% |
| 823 | 2 | 1.5% |
| 919 | 2 | 1.5% |
| 74 | 1 | 0.7% |
| 75 | 1 | 0.7% |
| 254 | 1 | 0.7% |
| 422 | 1 | 0.7% |
| 514 | 1 | 0.7% |
| 525 | 1 | 0.7% |
| 531 | 1 | 0.7% |
| 551 | 1 | 0.7% |
| 571 | 1 | 0.7% |
| 592 | 1 | 0.7% |
| 593 | 1 | 0.7% |
| 633 | 1 | 0.7% |
| 653 | 1 | 0.7% |
| 723 | 1 | 0.7% |
| 732 | 1 | 0.7% |
| 791 | 1 | 0.7% |
| 835 | 1 | 0.7% |

## *Protocol Table 6*
## *Item 7.B: HVAC Market Segment Data*
## *by 3-Digit SIC Code*
## *PG&E Study ID # 404B*

| Industry (3-Digit SIC Code) | HVAC | |
|---|---|---|
| | # of Part. | % of Part. |
| 836 | 1 | 0.7% |
| 864 | 1 | 0.7% |
| 871 | 1 | 0.7% |
| 873 | 1 | 0.7% |
| 943 | 1 | 0.7% |
| 944 | 1 | 0.7% |
| **TOTAL** | **137** | **100.0%** |

## *PROTOCOL TABLE 7*

## *PRE-1998 COMMERCIAL EEI PROGRAM CARRY-OVER EVALUATION OF HVAC TECHNOLOGIES PG&E STUDY ID #404B*

The purpose of this section is to provide the documentation for data quality and processing as required in Table 7 of the California Public Utility Commission (CPUC) Evaluation and Measurement Protocols (the Protocols). Although other important considerations are addressed throughout this section, major topics are organized and presented in the same order as they are listed in Table 7 for ease of reference and review. When responses to the items are discussed in detail elsewhere in the report, only a brief summary will be given in this section to avoid redundancy.

### *A. OVERVIEW INFORMATION*

### *1. Study Title and Study ID Number*

*Study Title:* Evaluation of PG&E's Pre-1998 Commercial EEI Program Carry-Over for HVAC Technologies.

*Study ID Number:* 404B

### *2. Program, Program Year and Program Description*

*Program:* Pre-1998 PG&E Commercial EEI Program.

*Program Year:* Rebates Received in the 1998 Calendar Year.

*Program Description:*

The Commercial Energy Efficiency Incentives Program for HVAC technologies offered by PG&E has three primary components: the Retrofit Express (RE) Program, the Retrofit Efficiency Options (REO) Program and the Advanced Performance Options (APO) Program.

The RE and REO Programs offer fixed rebates to PG&E's customers that install specific gas or electric energy-efficient equipment in their facilities. Both Programs cover most common energy-saving measures: lighting, air conditioning, refrigeration/food service, and motors. To receive a rebate, the customer is required to submit proof of purchase along with the application. The RE Program is primarily marketed to small and medium commercial, industrial, and agricultural customers. The maximum total rebate amount of the RE Program is $300,000 per account. This includes participation in any combination of the lighting, air conditioning, refrigeration/food service, and motor program options.

For the REO Program, customers are 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 work with customers to identify cost-effective improvements, with special emphasis on operational and maintenance measures at the customers' facilities. Marketing efforts are coordinated amongst PG&E's divisions, emphasizing local planning areas with high marginal electric costs to maximize the program's benefits.

The APO program included all HVAC technologies that were not covered under other PG&E rebate programs. The APO program targeted commercial, industrial, and agricultural market segments most likely to benefit from these unique projects. 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 that required a customized evaluation approach, as opposed to a prescriptive approach.

### 3. *End Uses and/or Measures Covered*

*End Use Covered:* HVAC Technologies.

*Measures Covered:* For the list of Program measures covered in this evaluation, see Attachment 3, Exhibit 3-26.

### 4. *Methods and Models Used*

The PG&E Commercial HVAC Technologies consisted of three key analysis components: engineering analysis, billing data regression analysis, and net-to-gross analysis. This integrated approach reduces a complicated problem to manageable components, while incorporating the comparative advantages of each analysis method. This approach describes per-unit net impacts as follows:

Net Impact = (Gross Impact) x (SAE Realization Rate) x (Net-to-Gross)

**Gross Impact** -- Gross impact is computed as the change in energy consumption for a particular HVAC technology relative to a baseline, typically defined by Title 24, and computed using CEC long term weather data. A detailed discussion of the HVAC impact calculations can be found in *Section 3.2*.

**SAE Realization Rates** -- The SAE Realization Rates were estimated based on a Statistically Adjusted Engineering (SAE) analysis using cross-sectional time series data and incorporating prior engineering estimates. As a result, the SAE realization rates could be defined as the percentage of a savings estimate that is detected or realized in the statistical analysis of actual changes in energy usage. The SAE realization rates were then applied to an impact estimate based upon the program baseline, equipment purchased under the program, and typical weather. A detailed discussion of the final SAE model specification can be found in *Section 3.3*.

**Net-to-Gross** -- The net-to-gross (NTG) ratio adjusts the program baseline derived from estimates of free ridership and spillover associated with the program. Two approaches were used to capture the NTG effect: (1) a discrete choice model used to estimate free ridership and spillover effects and (2) the NTG ratio calculation based on survey self report using a representative nonparticipant sample to account for naturally occurring conservation. The

NTG analysis approach is presented in detail in *Section 3.4*. A third approach using the net billing model was used to verify the results of the first two approaches, and is described in detail in *Section 3.3.9*.

### *5. Participant and Comparison Group Definition*

#### Participant

Participants are defined as those PG&E commercial customers who received PG&E rebates in the 1998 calendar year for installing at least one HVAC measure under the CEEI Program.

#### Comparison Group

The comparison group for this study is defined as a group of PG&E commercial customers who did not receive any HVAC end-use rebates in the 1998 calendar year under the CEEI Program, and who share as many characteristics as possible with the commercial sector participant group in terms of annual usage and business type distribution. Customers who participated in previous years or those who simply participated by installing a non-HVAC end-use measure, are eligible for the comparison group.

### *6. Analysis Sample Size*

The final analysis dataset has 703 observations based upon 703 telephone survey. The distribution of the sample by business type and technology is presented in *Section 3.1*.

## *B. DATABASE MANAGEMENT*

### *1. Data Description and Flow Chart*

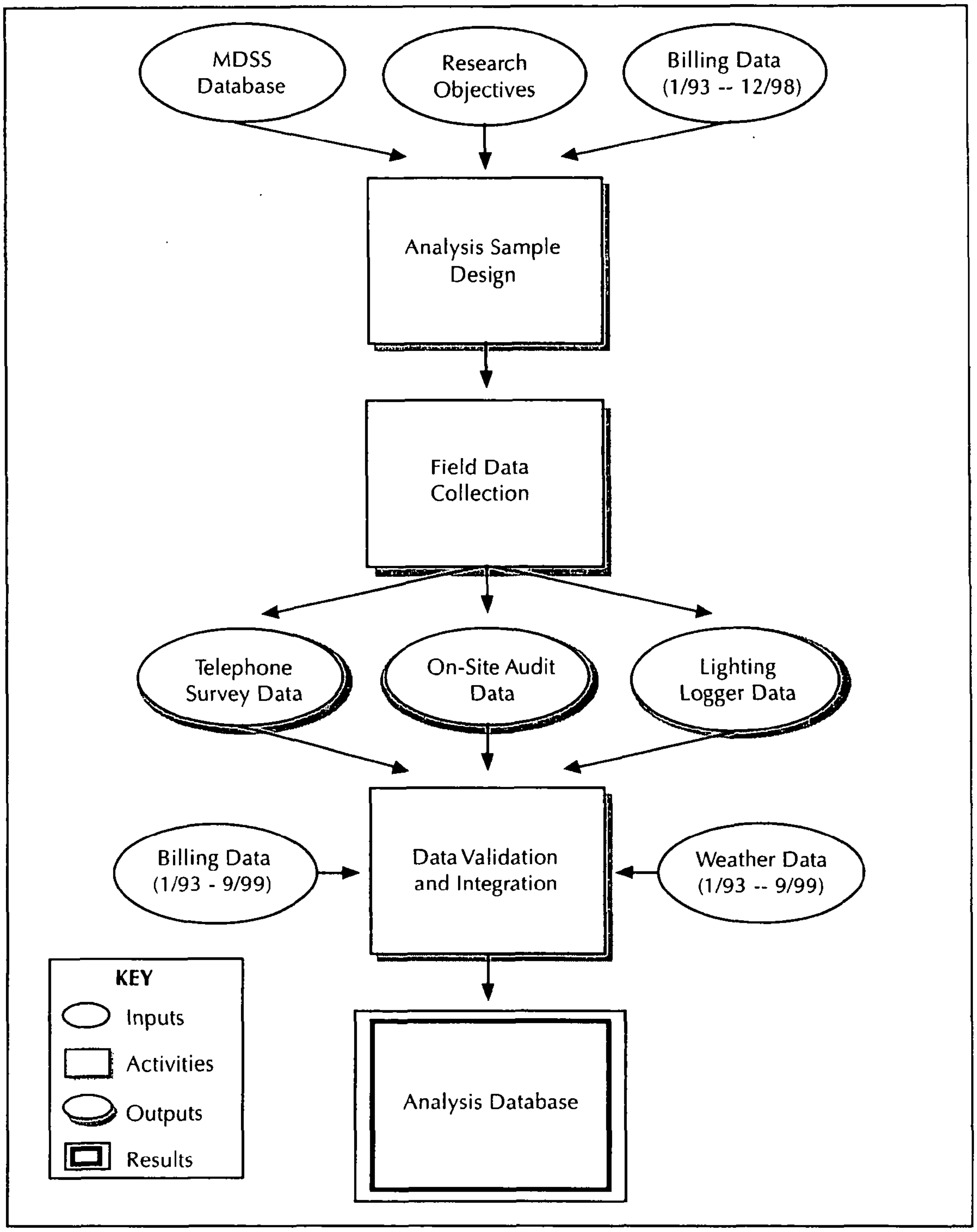
All data elements mentioned above were linked to the final analysis database through the unique customer identifier -- the evaluation 'site_id' variable. For this evaluation, the analysis database served as a centralized tracking system for each customers' billing history, program participation, and sampling status, which helped to reduce data problems such as account mis-match, double counting, or repeated customer contacts. Exhibit A below illustrates how each key data element was used to create the final analysis database for the Evaluation.

### *2. Key Data Elements and Sources*

A complete list of data elements and their sources can be found in *Section 3.1*. The key analysis data elements and their sources are listed below:

**Program Participant Tracking System.** The participant tracking system for the RE, REO and APO programs was maintained as part of the PG&E MDSS. It contains program application, rebate, and technical information about installed measures, including measure description, quantity, rebate amount, and ex ante demand, energy, and therm saving estimates.

*Exhibit A*
*Analysis Database Development*



**PG&E Billing Data.** The PG&E billing data were obtained from two separate data requests. The original nonresidential billing dataset contains monthly energy usage for all nonresidential accounts in PG&E's service territory, and was used in the sample design as described in *Section 3.1*. The billing histories contained in this database run for 1993 through 1998.

The second billing dataset, was later obtained from PG&E's Load Data Services.[1] This billing dataset contains bill readings that run for January 1999 through September 1999, and was therefore used in the billing regression analysis. In addition, the billing series from this database is the PG&E pro-rated monthly usage data, a series calculated by PG&E for each calendar month.

**Telephone Survey Data.** Two telephone survey samples (255 participants and 589 comparison group customers) were collected as part of this evaluation. They were designed to be representative of the population of each business type. The telephone survey supplies information on customer decision-making, equipment operating characteristics, equipment stocks, and energy-related changes at each site for the billing period covered by the statistical billing analysis.

**On-Site Audit Data.** On-site audit data were collected as part of this evaluation for both the participant and comparison group. The on-site audit is designed to support the telephone sample for the largest participation segments. This sample contributes site-specific equipment details, and better estimates of operating hours and operating factors. There were a total of 64 participant on-site audits conducted for this HVAC end-use evaluation.

**End Use Logger Data.** The logger data collected for the 1997 CEEI Evaluation provided operating information for central air conditioner (CAC) measures. For the CAC measures, the logger data are used to calibrate the DOE-2.1 E Models.

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

Other data elements include PG&E program marketing data, PG&E internal SIC code mapping/segmentation scheme, program procedural manuals and other industry standard data sources.

### 3. *Data Attrition Process*

All data elements mentioned above were first validated and then merged together to form the final analysis dataset. Records with out-of-range or questionable data were either deleted or flagged to ensure that only those records with sufficient data, both in terms of data quality and

[1] A preliminary analysis has concluded that the monthly usage and bill read date information in these two datasets is consistent.

representativeness, were used in the analysis. The key data attrition decisions are summarized in *Section 3.3.5.*

### *4. Internal Data Quality Procedures*

The evaluation contractor of this project, Quantum Consulting Inc. (QC), has performed extensive data quality control on all categories of program data, including utility billing data, program tracking data, telephone survey data, and on-site audit data. QC's data quality procedures are consistent with PG&E's internal database guidelines and the guidelines established in the Protocols.

Throughout the course of sample design and creation, survey data collection, and data analysis, several data quality assurance procedures were in place to ensure that all energy usage data used in analysis and all telephone survey data collected was of high quality and would prove useful in later analysis. The stages of data validation undertaken and the methods employed are detailed below:

**Pre-Survey Usage and Account Characteristic Data Validation.** The goal of this stage of data validation was to screen out customers who had unreasonable or unreliable usage data, or who had changes in key elements of their billing data over the 1996 to 1998 period. Accounts for which changes were observed in account numbers, service addresses, SIC codes, electric rate schedules, electric meter numbers, or corporation and premise identification variables, were excluded from sample eligibility. Usage data reliability screening first eliminated from the sample, all accounts which experienced service interruptions, exhibited inconsistent read dates, or for which bills were estimated. Additionally, based on comparisons of account usage between years, and between different months in the same year, customers with unusual usage patterns such as unusually high variation in monthly or yearly usage were given special attention and, in some cases, excluded from the sample frame. A more detailed discussion of the steps undertaken in the pre-survey usage and account characteristics data validation, is provided in the discussion of survey sample creation in *Section 3.1.*

**Real Time Survey Data Validation.** Survey data collection was performed using QC's 24 station Computer Aided Telephone Interviewing (CATI) center. Data entry applications, programmed using a third-party software package, employed logical branching routines and real-time data validation procedures to ensure that survey questions were appropriate for each customer's situation and that recorded responses were reasonable and logical. Data entry applications also performed real time range checks and field protection for out of range values during the data collection process thereby affording an additional means of ongoing data validation. Finally, because the software package used to program the data collection software could output the survey data in the form of a SAS dataset, the survey data was on-line continuously throughout the course of data collection. This allowed for the generation of frequency distributions and cross-tabs on data at regular stages throughout the survey fielding to facilitate QC's internal early detection and correction of data entry errors.

**Final Survey Data Validation.** Following the completion of survey data collection, all data was subjected to a final stage of validation and cleaning during which illogical responses were identified and corrected or flagged, and corrections were made to any mis-coding of data not detected in earlier stages of cleaning and validation. All activities undertaken in the course of survey were documented in accordance with QC's Enumerated Quality Assurance Logs and Standards (EQUALS) survey data collection documentation Protocols.

### 5. *Unused Data Elements*

Without exception, all data collected specifically for the Evaluation were utilized in the analysis.

## C. *SAMPLING*

### 1. *Sampling Procedures and Protocols*

Program participants who were paid a rebate in 1998 were in most part carryover applicants. Their projects were initiated prior to 1997 but they only applied or received a rebate in 1998 when their projects reached the final implementation stage. There were a total of 137 HVAC sites, 99 standards and 38 customs, that received a rebate from PG&E in 1998. A complete census of the population was needed to meet the goals of the telephone survey.

The primary objective of the nonparticipant telephone sample is to provide a control group for the net and gross billing analyses. The final comparison group sample frame consists of 192,689 commercial customers drawn from an eligible population of over 400,000. 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 annual non-missing, non-zero usage values for 1997, 1998, and 1999. Customers with zero, or missing billing data, were removed from the sample.

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. The final sample design includes 48 segments classified by size according to energy usage.

The desired nonparticipant quota was 500 points, but the quota was targeted at approximately 600 points with the assumption that for certain segments with small available sample frames, such as the "Very Large" segment, the quota would not be filled. The final sample allocation was randomly selected within each customer segment.

The canvass sample included 50,000 randomly drawn customers within PG&E's service territory. It's primary function was to support the net-to-gross analysis by identifying nonparticipants who have installed program qualifying measures outside of the rebate programs. The sample design focused on identifying only nonparticipants who were not rebated in 1998. From a sample of 50,000 customers, the sample quota was targeted for 4,000 total completes with about 500 of the 4,000 having made lighting or HVAC changes.

Finally, the achieved samples and their distributions can be found in *Section 3.1*. Based on the total energy usage, the sample relative precision's were estimated to be well under 10 percent at the 90 percent level. The procedures used in the relative precision calculation and a summary of how the Evaluation sample design meets the Protocols' requirement in terms of sample size and relative precision are presented in *Section 3.1*.

### 2. *Survey Information*

Telephone survey instruments are presented in the *Survey Appendices, Appendix A* (for participants) and *Appendix B* (for comparison group customers). Participant and comparison group customer's survey response frequencies are presented in *Appendices E* and *F*, respectively. Finally, reasons for refusals are presented in *Appendices K* and *L*.

On-site audit instruments are presented in the *Survey Appendices, Appendix D*.

### 3. *Statistical Descriptions*

As mentioned above, a complete set of participant and comparison group customer's responses frequencies are presented in *Survey Appendices E* and *F*. In addition, statistics on usage and engineering impact variables that were used in the billing data regression models are also presented in *Section 3.3*.

## D. *DATA SCREENING AND ANALYSIS*

A detailed discussion of the billing data regression data analysis is presented in *Section 3.3*. The statistical billing model described in this section incorporates analysis for two distinct end uses: lighting and HVAC (for Study ID's 404A and 404B respectively). Specific procedures and modeling issues are discussed below.

### 1. *Outliers, Missing Data and Weather Adjustment*

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 criteria:

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

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

Finally, customers were removed from the analysis if they had a measure installed under the program that would result in an increase in usage. These individuals were identified through customer interviews.

Note that only 14 nonparticipants were deleted, whereas 28 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 drawn as a census and no pre-screening was done on their billing data prior to being selected into the participant survey sample frame. Of the 28 participants, 18 were deleted due to the zero bill criteria.

### 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. There were 15 participants that were identified as having total Commercial Sector Program energy impacts that were greater than their pre-installation, and were dropped from the analysis. The large majority of these customers were also found to have invalid usage.

### Large Customers

Customers whose annual pre-installation energy consumption exceeded three million kWh were excluded from the billing analysis. A total of 40 participants and 58 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 previous three Lighting Evaluations, all of which were unsuccessful in obtaining reliable results when including customers with usage above this level. This is also consistent with the recommendations made by the Verification Reports of PG&E's 1995 through 1997 Commercial Lighting Evaluations, which stated in 1995 that "program effects can be difficult to detect for large customers," and recommended censoring large customers for 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.

In summary, out of the original sample frame of 589 nonparticipants, 71 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 255 HVAC and lighting participants, 70 were removed because of bad billing, improper site aggregation, or because they were large customers.

*Section* 3.3 presents the number of participants that were removed from the analysis for each of the above criteria.

### 2. *Background Variables*

Background variables, such as interest rates, unemployment rates and other economic factors, were not explicitly controlled for in the final model, However, the effect of these factors was explicitly accounted for when a cross-sectional time series model was used with a comparison group. This is based on the assumption that the comparison group was equally impacted by the same set of background variables.

### 3. *Data Screen Process*

As explained in *Section 3.3*, the final model was fitted in two steps. The first step is to estimate a baseline model to develop the relationship between the pre-installation year usage and the post-installation year usage, followed by an SAE model to estimate the SAE realization rates based on the engineering estimates of program impacts. Section 1 above describes in detail all of the data screening criteria. *Section* 3.3 also details the number of customers that were screened for each criteria.

### 4. *Regression Statistics*

The billing regression analysis for the lighting program uses two different multivariate regression models under an integrated framework of providing unbiased and robust model estimates in the commercial sector. The key feature of our approach is that it employs a simultaneous equation method to account for both the year-to-year and cross-sectional variations in a manner that consistently and efficiently isolates program impacts.

A baseline model is initially estimated using only the comparison group sample. This model estimates a relationship that is then used to forecast the post-installation-year energy consumption for both participants and the comparison group, as a function of pre-installation-year usage. In this way, baseline energy usage is forecasted for participants by assuming that their usage will change, on average, in the same way that usage did for the comparison group. The outputs of the baseline model are presented in *Section 3.3*.

The estimated SAE realization rates are used to adjust the engineering estimates of expected annual energy impacts for the entire participant population. The regression statistics for the final SAE model are presented in the following exhibit, and a more detailed discussion can be found in *Section 3.3*.

The dependent variable is the difference between the actual and predicted 1999 usage using the 1997 baseline model.

SAE coefficients are calculated for six 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 compact and standard fluorescent installations at the same site in office buildings. Therefore, there was enough correlation between the compact and fluorescent 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 lighting fixtures being installed at the same premise, the level of segmentation for the lighting population was conducted by business type.

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, as well as changes made to the size (square footage) of the building and with the number of employees. Separate change variables were developed for participants and nonparticipants.

*Exhibit B*
*Final SAE Model Output*

| Parameter Descriptions | Analysis Variable Name | Units | Parameter Estimate | t-Statistic | Sample Size |
|---|---|---|---|---|---|
| **SAE Coefficients** | | | | | |
| **Lighting End Use** | | | | | |
| Lighting Offices | LGTOFF7 | kWh | -0.824743 | -3.05 | 50 |
| Lighting Retails | LGTRET7 | kWh | -0.891237 | -1.32 | 23 |
| Lighting Schools | LGTSCH7 | kWh | -0.779395 | -1.01 | 14 |
| Lighting Miscellaneous | LGTMSC7 | kWh | -0.596705 | -1.34 | 56 |
| **HVAC End Use** | | | | | |
| Retrofit Express Measures | RETXHVC | kWh | -1.150815 | -1.38 | 42 |
| Custom HVAC | CUSTHVC | kWh | -0.757689 | -1.36 | 6 |
| **Other End Uses** | | | | | |
| Other Impacts | OTHMEAS7 | kWh | 0.100398 | 0.05 | 18 |
| **Change Variables** | | | | | |
| Part Lighting Changes | LGT_CHG7 | kWh | -0.019670 | -0.72 | 18 |
| Part HVAC Changes | AC__CHG7 | kWh | -0.064773 | -2.53 | 28 |
| Part Other Equipment Changes | OTH_CHG7 | kWh | -0.025256 | -0.38 | 4 |
| Part Square Footage Changes | SQFT_CH7 | # Sqft*kWh | 11.647230 | 4.79 | 6 |
| Part Employee Changes | EMP_CHG7 | # Emp*kWh | 611.527341 | 1.27 | 27 |
| Part EMS Changes | EMS_CHG7 | kWh | 0.049254 | 2.64 | 38 |
| Nonpart Lighting Changes | LGT_NON7 | kWh | 0.100211 | 5.94 | 60 |
| Nonpart HVAC Changes | AC__NON7 | kWh | 0.008429 | 0.60 | 71 |
| Nonpart Other Equipment Changes | OTH_NON7 | kWh | -0.035692 | -1.86 | 42 |
| Nonpart Square Footage Changes | SQFT_NO7 | # Sqft*kWh | -1.012276 | -1.60 | 20 |
| Nonpart Employee Changes | EMP_NON7 | # Emp*kWh | 332.980301 | 3.38 | 598 |
| Nonpart EMS Changes | EMS_NON7 | kWh | -0.024088 | -2.54 | 82 |

## 5. *Model Specification*

The model specifications are presented in *Section 3.3*. Specific model specification issues are further discussed below:

**Cross-sectional Variation.** The final model specification recognizes the potential heterogeneity problem in the model and uses the following procedures to eliminate the impacts of the cross-sectional variation: (1) observations with highest usage values were removed in the model to reduce the overall variance of the sample in terms of usage and size; and (2) independent variables were all interacted with the pre-installation usage to ensure that change of independent variable will be proportional to the usage value.

**Time Series Variation.** The key factors to control for the time series variation in the final model are: (1) use of the comparison group to define the relationship of the energy consumption between two different time periods and (2) elimination of the multiple time period interactions by only one yearly pre-installation period and one yearly post-installation period for each stage.

**Self-selection.** One solution to the problem of self-selection in the gross billing model is to include an Inverse Mills Ratio in the model to correct for self-selection bias. This method was addressed by Heckman (1976, 1979[2]) and is used by others (Goldberg and Train, 1996[3]). Goldberg and Train 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. A complete description of the methods used to calculate the Inverse Mills Ratios, and the results of the net billing model, are described in detail in *Section 3.3.9*.

**Collinearity.** Various statistical tests (such as COLLIN and VIF options in SAS) were used to check multiple collinearity problem among independent variables in the model to ensure that the final parameter estimates are robust.

**Net Impact.** As mentioned in the Self-selection section above, a net billing model was implemented using the double inverse Mills ratio approach. The net billing model's estimates of the term (1-FR) were used to verify the results of the self-report and discrete choice models. The net billing model's estimates of (1-FR) were the highest of all three models tests. To be conservative, a the net impacts were derived from the gross billing analysis model and adjusted by a net-to-gross ratio using self-report methods. For a detailed discussion on the selection of the NTG ratios, refer to *Section 3.4.4*.

### *6. Measurement Errors*

For the billing data regression analysis, the main source of measurement errors is the telephone survey. Our approach has been to proactively stop the problem before it happens so that statistical corrections are kept to a minimum.

Measurement errors are a combination of random and non-random error components that plague all survey data. The non-random error frequently takes the form of systematic bias, which includes, but is not limited to, ill-formed or misleading questions and mis-coded study variables. In this project, we have implemented several controls to reduce systematic bias in the data. These steps included: (1) thorough auditor/coder training; (2) instrument pretest; and (3) cross-validation between on-site audit data and telephone survey responses.

The random measurement error, such as data entry error, has no impact on estimating mean values because the errors are typically unbiased. For the measures that were modeled in the billing regression analysis, the impact of random unbiased measurement errors was accounted for as part of the overall standard variance in the parameter estimate.

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[2] 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.

[3] 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.

### 7. *Autocorrelation*

The autocorrelation problem exists if the residuals in one time period are correlated with the residuals in the previous time period. Since the final model is based on a yearly pre- and post-installation period comparison with only one year in each period, the autocorrelation problem was unlikely to occur under this scenario, as was confirmed by examining the Durbin-Watson statistic for these models.

### 8. *Heteroskdasticity*

See discussion above.

### 9. *Collinearity*

See discussion above.

### 10. *Influential Data Points*

See discussion above.

### 11. *Missing Data*

See discussion above.

### 12. *Precision*

The precision calculation for the gross SAE realization rates are presented in *Section 3.3*. Relative precision's for net estimates were calculated using the following procedure:

- First, NTG ratios, $N_i$, were computed for all technology groups that were represented in the telephone survey.

- Then, the program level NTG and program level standard error for the NTG were calculated using the classic stratified sample techniques. The program level NTG was a weighted average of technology level NTG values with adjusted gross impacts per technology group providing the weights.[4] The functional relation can be best described in the following equations:

$$\overline{N} = \sum_i w_i * \overline{N_i} \text{ with } w_i = MWh_i$$

$$StdErr_{NTG} = \sqrt{\sum_i \left[ (w_i)^2 * StdErr_i^2 \right]}$$

Where,

$NTG$ = Net-to-Gross Value;

$i$ = Technology Group i; and,

$w_i$ = Weight of technology group i.

- Then, the relative precision[5] for the program NTG value for energy was calculated and combined with the relative precision of the gross energy impact to yield an overall relative precision for the net energy impacts:

$$RP_{NTG\_Energy} = \frac{t_{\alpha=10} * StdErr}{NetMWh}$$

$$RP_{NetEnergy} = \sqrt{RP^2_{NTG\_Energy} + RP^2_{GrossEnergy}}$$

- Finally, the relative precision net demand impacts were calculated using a scaled version of the relative precision for the net energy impact. The sample sizes of the on-site audits and telephone surveys served as the scalars:

$$RP_{NetDemand} = RP_{NetEnergy} * \sqrt{\frac{N_{OnSite}}{N_{Telephone}}}$$

- Per-unit NTG relative precision data appearing in Table 6 (Items 1-5) were calculated in a similar fashion.

[4] Technology groups with no standard errors were excluded from this calculation.

[5] The example shown is for the 90 percent confidence level. Relative precision was also calculated at the 80 percent confidence level.

## *E. DATA INTERPRETATION AND APPLICATION*

The program net-to-gross analysis was conducted based on survey self-report. For a detailed NTG analysis discussion, see *Section 3.4.*

### Self Report Method

The self-report method used to score free-ridership uses participant responses to survey questions regarding the timing of and reasons for equipment replacement actions. The complete text of the participant surveys may be found in the *Survey Appendices, Appendix A*. Questions used for the self-report analysis are summarized in *Section 3.4*.

The net-to-gross ratio using the self-report method included estimates of free-ridership and spillover. These results yielded the lowest estimates of net participation, and were used in all circumstances.

*Attachment 5*

*PG&E Retroactive Waiver for Pre-1998 CEEI Program Carry-Over:*

*Lighting and HVAC End Uses, Net-to-Gross Analysis*

# PACIFIC GAS & ELECTRIC COMPANY
# RETROACTIVE WAIVER FOR
## Pre-1998 CEEI PROGRAM CARRY-OVER: LIGHTING AND HVAC END USES
**Net-to-Gross Analysis**
**STUDY IDs: 404a & 404b**
**Date Approved: 5/20/99**

## Program Background

Pacific Gas & Electric Company (PG&E) fielded DSM programs to the Commercial sector (among others) prior to 1998. The primary purpose of the Pre-1998 Commercial Energy Efficiency Incentives Program (Program) was to promote the installation of energy efficient equipment retrofits. The Program offered a wide variety of energy efficient prescriptive lighting and HVAC measures ranging from compact fluorescent lamps to custom non-prescriptive lighting and HVAC measures. The impact evaluation associated with this waiver is designed to assess the actual load impacts resulting from the lighting and HVAC measures committed under the pre-1998 Programs but rebated during 1998 (Carry-Over).

**Pre-1998 Program Carry-Over Summary: Indoor Lighting End Use**

| Technology | Unique Sites | Avoided Cost | Percentage of Avoided Cost |
|---|---|---|---|
| Compact Fluorescent Lamps | 164 | 1,224,634 | 13.8% |
| Controls | 65 | 348,665 | 3.9% |
| Customized Lighting | 3 | 16,694 | 0.2% |
| Delamp Fluorescent Fixtures | 106 | 2,083,451 | 23.6% |
| Efficient Ballast Changeouts | 35 | 26,744 | 0.3% |
| Exit Signs | 108 | 201,030 | 2.3% |
| Halogen | 15 | 2,447 | 0.0% |
| High Intensity Discharge | 19 | 325,393 | 3.7% |
| T-8 Lamps and Electronic Ballasts | 371 | 4,615,941 | 52.2% |
| **TOTAL (Unique Sites)** | 474 | 8,844,997 | 100.0% |

**Pre-1998 Program Carry-Over Summary: HVAC End Use**

| Technology | Unique Sites | Avoided Cost | Percentage of Avoided Cost |
|---|---|---|---|
| Adjustable Speed Drives | 20 | 456,485 | 4.7% |
| Central A/C | 63 | 251,301 | 2.6% |
| Convert To VAV | 2 | 222,348 | 2.3% |
| Cooling Towers | 4 | 167,833 | 1.7% |
| Customized Controls | 5 | 304,060 | 3.1% |
| Customized EMS | 13 | 1,012,859 | 10.4% |
| High Efficiency Gas Boilers | 1 | 8,066 | 0.1% |
| Other Customized Equip | 6 | 2,252,416 | 23.2% |
| Other HVAC Technologies | 3 | 657,368 | 6.8% |
| Package Terminal A/C | 12 | 41,720 | 0.4% |
| Reflective Window Film | 24 | 62,266 | 0.6% |
| Set-Back Thermostat | 20 | 49,780 | 0.5% |
| Water Chillers | 17 | 4,223,765 | 43.5% |
| **TOTAL (Unique Sites)** | 164 | 9,710,268 | 100.0% |

**Proposed Waiver**

This waiver requests deviations from the Protocols[1] by PG&E for the pre-1998 Commercial Sector Carry-Over Evaluation, lighting and HVAC end uses. PG&E seeks CADMAC approval to allow the use of self-report based algorithms to estimate free ridership and spillover effects for certain technologies should the discrete choice and LIRM models fail to produce statistically reliable results of net-to-gross estimates. Therefore, the self-report methodology would only apply to those technologies (not the entire end-use) for which the discrete choice and LIRM models fail to produce statistically reliable results. This waiver is very similar to one submitted and approved by the CADMAC on January 20, 1999.

**Rationale**

It is our expectation that the discrete choice model will provide statistically reliable results for all lighting technologies, as was the case in the 1996 and 1997 evaluations. However, because this is a carry-over year, participation in the HVAC end use was very low. Therefore, we do not expect to have sufficient sample sizes to implement a discrete choice model for HVAC measures. Furthermore, for custom types of HVAC installations and lower penetrated HVAC technologies, sample sizes of nonrebated installations are also too small to implement a discrete choice model. In addition, low levels of participation for HVAC technologies also reduce the likelihood of obtaining statistically reliable results from a LIRM model.

If, after following procedures that are generally accepted as best practices for developing statistical models (see Table 7 of the Protocols) we are unable to build a reliable discrete choice model or LIRM for certain technologies, we propose relying on the self-report estimates of free-ridership and spillover. Methods used for the self-report analysis will follow the Quality Assurance Guidelines, and are documented in previous PG&E Evaluation Research Plans and Final Reports, which have been submitted to the ORA.

The primary reason why the discrete choice model may not be used for some technologies is an insufficient number participants, as well as an insufficient number of nonparticipant adoptions identified in the nonparticipant and canvass survey. For example, we do not expect to find a sufficient number of cooling tower adoptions to warrant its inclusion in the discrete choice model. Examples of conditions that could lead to the rejection of the net LIRM approach might include the following: (1) a small number of observations control the model results; (2) intractable collinearity; or (3) intractable nonsignificant t statistics. Based on our experience (particularly with the HVAC end use), we believe these problems (and possibly others) are very likely to materialize. The prevailing criterion for assessing this decision would be that a verification study or peer review would lead to a similar conclusion. Results from all three models will be presented in the final Study, as they were for the 1996 and 1997 evaluations.

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[1] Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings for Demand-Side Management Programs, as adopted by California Public Utilities Commission Decision 93-05-063, revised March 1998.