Customer Energy Efficiency Program
Measurement and Evaluation Program

# IMPACT EVALUATION OF PACIFIC GAS & ELECTRIC COMPANY'S 1997 AGRICULTURAL PROGRAMS ENERGY EFFICIENCY INCENTIVES PROGRAM:

## PUMPING AND RELATED END USE (STUDY ID 335A), REFRIGERATION END USE (STUDY ID 335B), & GREENHOUSE HEAT CURTAIN END USE (STUDY ID 335C)

***March 1, 1999***

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**Equipoise Consulting, Inc.**

Energy Analysis

Project Management

Training

# Final Report for

# Pacific Gas & Electric's
# 1997 Agricultural Programs

Submitted by:

**Equipoise Consulting Incorporated**

in association with
**California AgQuest Consulting and**
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# 1. EXECUTIVE SUMMARY

## *1.1 Evaluation Impact Summary*

This report presents the results of the impact evaluation of Pacific Gas & Electric Company's (PG&E's) 1997 agricultural (Ag) sector programs. The evaluation assessed the impacts for PG&E's agricultural customers who received rebates during 1997 under the Nonresidential Energy Efficiency Incentive (EEI) programs. The evaluation of the 1997 Agricultural Energy Efficiency Incentives (AEEI) Programs covered three end uses – pumping and related, refrigeration, and greenhouse heat curtain. These end uses comprised 90% of the agricultural sector avoided costs. This executive summary is divided into three sections: evaluation impact summary, major findings, and major recommendations.

### 1.1.1 Overall Results

The assessed (ex post) impacts were 81% of the predicted (ex ante) energy, 51% of the ex ante demand, and 65% of the ex ante therm estimates. The summary is shown in Exhibit 1.1.

**Exhibit 1.1**
**Summary of Gross and Net Load Impacts**
**1997 Agricultural EEI Programs**

| Agricultural Energy Efficiency Incentives Programs | Gross Savings | Gross Realization Rate | Net To Gross | Net Savings | Net Realization Rate |
|---|---|---|---|---|---|
| **EX ANTE** | | | | | |
| **kW** | 3,991 | - | 0.75 | 2,993 | - |
| **kWh** | 12,748,623 | - | 0.75 | 9,561,467 | - |
| **Therms** | 580,625 | - | 0.75 | 435,469 | - |
| **EX POST** | | | | | |
| **kW** | 2,037 | 0.51 | 0.75 | 1,528 | 0.51 |
| **kWh** | 10,247,327 | 0.80 | 0.75 | 7,685,495 | 0.80 |
| **Therms** | 380,118 | 0.65 | 0.75 | 285,088 | 0.65 |

As part of a retroactive waiver agreement with California Demand Side Management Advisory Group (CADMAC), PG&E is allowed to use a default net-to-gross ratio of 0.75 in return for conducting a telephone-survey based market effects study of four key market barriers for the AEEI pumping and pumping related end-use market segment. The results of the market effects study are presented in a separate report.

### 1.1.2 AEEI Pumping and Related End Use Impacts

Exhibit 1.2 shows the results of the pumping and related end-use impacts. This end use consisted of the measures of pump repair, low-pressure sprinkler nozzles, and micro-irrigation conversion.

**Exhibit 1.2**
**Summary of Gross and Net Load Impacts**
**Pumping and Related End Use**

| End Use Pumping and Related | Gross Savings | Gross Realization Rate | Net To Gross | Net Savings | Net Realization Rate |
|---|---|---|---|---|---|
| **EX ANTE** | | | | | |
| **kW** | 3,274 | - | 0.75 | 2,456 | - |
| **kWh** | 8,592,622 | - | 0.75 | 6,444,466 | - |
| **Therms** | - | - | - | - | - |
| **EX POST** | | | | | |
| **kW** | 1,451 | 0.44 | 0.75 | 1,088 | 0.44 |
| **kWh** | 5,934,091 | 0.69 | 0.75 | 4,450,568 | 0.69 |
| **Therms** | - | - | - | - | - |

The micro-irrigation conversion measure was slightly more than one-half of the expected energy and more than three-quarters of the expected demand impacts. As such, its lower realized savings affected the demand impacts more than the energy impacts. Key impact-related points for the pumping and related end use are:

- The micro-irrigation conversion sites pumped much less water than expected from the ex ante estimates. Additionally, the pressure differences between the pre- and post-retrofit systems were lower than expected. This decreased both the energy and demand impacts for this measure.
- No demand impact was found for the pump repair measure, despite ex ante estimates that an impact existed. This finding, in conjunction with the lower than expected demand impact found for the micro-irrigation conversion, resulted in a low overall kW realization rate for this end use.
- Two of the five low-pressure sprinkler sites had zero impacts due to improper use of the measure for energy efficiency purposes.

### 1.1.3 Refrigeration End Use

Exhibit 1.3 shows the results of the refrigeration end use. This end use consisted of the measures of oversized condensers, strip curtains, and non-electric condensate evaporators for refrigerators and freezers.

**Exhibit 1.3**
**Summary of Gross and Net Load Impacts**
**Refrigeration End Use**

| End Use Refrigeration | Gross Savings | Gross Realization Rate | Net To Gross | Net Savings | Net Realization Rate |
|---|---|---|---|---|---|
| **EX ANTE** | | | | | |
| kW | 416 | - | 0.75 | 312 | - |
| kWh | 2,392,698 | - | 0.75 | 1,794,523 | - |
| Therms | - | - | - | - | - |
| **EX POST** | | | | | |
| kW | 285 | 0.69 | 0.75 | 214 | 0.69 |
| kWh | 2,549,933 | 1.07 | 0.75 | 1,912,450 | 1.07 |
| Therms | - | - | - | - | - |

The oversized condenser measures represent more than 99% of the expected impacts for this end use and, therefore, controlled the realization rates. Key impact-related items for the oversized condenser applications are:

- The sites had higher effective full load hours of operation than predicted, leading to a realization rate more than 1.0.
- There were fewer tons of refrigeration used, on average, than predicted. This decreased the demand impact.

### 1.1.4 Greenhouse Heat Curtain End Use

Exhibit 1.4 shows the results of the greenhouse heat curtain end use. This end use consisted of the greenhouse heat curtain measure.

**Exhibit 1.4**
**Summary of Gross and Net Load Impacts**
**Greenhouse Heat Curtain End Use**

| End Use Greenhouse Heat Curtain | Gross Savings | Gross Realization Rate | Net To Gross | Net Savings | Net Realization Rate |
|---|---|---|---|---|---|
| **EX ANTE** | | | | | |
| kW | - | - | - | - | - |
| kWh | - | - | - | - | - |
| Therms | 580,625 | - | 0.75 | 435,469 | - |
| **EX POST** | | | | | |
| kW | - | - | - | - | - |
| kWh | - | - | - | - | - |
| Therms | 380,118 | 0.65 | 0.75 | 285,088 | 0.65 |

The key impact-related items are:

- There was a wide range of nighttime thermostat settings observed on site. The average was five degrees less than the ex ante estimate.

- The evaluation had less difference between the heat transfer coefficient (U-value) with and without the heat curtain than expected in the ex ante estimate.
- The evaluation team on-site audits found 88% of the rebated heat curtains. Some had been removed, while others had not yet been installed.

## *1.2 Major Findings*

The major findings from the evaluation are:

- Pump repairs do not save demand, only energy.
- Low-pressure sprinkler nozzle sites appear to use the measure in an inconsistent manner. Installation of the measure does not always save energy.
- There was no minimum thermostat setpoint required for the heat curtain measure.

## *1.3 Major Recommendations*

Based upon the findings, the major recommendations the evaluation team makes are:

- Set the demand impact to zero for a pump repair for any future programs.
- Require that the low-pressure sprinkler nozzles installed under the program reduce the pressure seen at the pump.
- Require heat curtain installations to maintain an average nighttime temperature of 65°F in order to qualify for the program.
- For the non-electric condensate Retrofit Express measure, use a list of eligible refrigerators and freezers, by manufacturer and model. This should expedite rebates and assure that the anticipated savings are achieved.
- For future evaluations, use of the PG&E pump test database to target which pump repair sites should receive evaluation post installation pump tests. This was a successful strategy in this evaluation.
- For future evaluations, require on-site audits of oversize condenser sites. Their complexity makes this approach mandatory.

# 2. INTRODUCTION

This section summarizes results of the impact evaluation of Pacific Gas & Electric Company's (PG&E's) 1997 agricultural (Ag) sector programs. The evaluation assessed the impacts for PG&E's agricultural customers who received rebates during 1997 under the Nonresidential Energy Efficiency Incentive (EEI) programs.

As illustrated in Exhibit 2.1, the Agricultural EEI (AEEI) participants who adopted pumping and related, refrigeration, and greenhouse heat curtain measures comprised 90% of the total agricultural sector avoided cost. Thus, these are the three AEEI end uses covered under this evaluation. The remaining agricultural customer EEI measures are accounted for as miscellaneous measures under Table C-9 of the "Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand Side Management Programs" (the Protocols). The AEEI programs include agricultural sector incentives paid under the Retrofit Express (RE) program and the Retrofit Efficiency Options (REO) program.

**Exhibit 2.1**
**Summary of Avoided Cost by**
**Agricultural Sector EEI Measure**

| End Use | PG&E Code * | Measure Description | N App. | Avoided Costs | Percentage*** |
|---|---|---|---|---|---|
| **Ag Pumping and Related** | A1 | Pump Retrofit | 111 | $ 1,051,755 | 14% |
| | A40 / A41 / A42 / A43 | Low-Pressure Nozzles | 5 | $ 34,166 | 0% |
| | A44 / A45 / A47 / A49 / A51 / A5 | Micro-Irrigation Conv. | 32 | $ 3,812,964 | 52% |
| | **Ag Pumping and Related End Use Total** | | 148 | $ 4,898,885 | **67%** |
| **Refrigeration** | R17 / R18 | High-Capacity Condenser | 10 | $ 879,621 | 12% |
| | R2 | Strip Curtains for Walk-In | 1 | $ 1,021 | 0% |
| | R52 | Condensate Evaporator | 2 | $ 887 | 0% |
| | **Refrigeration End Use Total** | | 13 | $ 881,528 | **12%** |
| **Greenhouse Heat Curtain Total** | A10 | Greenhouse Heat Curtain | 11 | $ 762,685 | **10%** |
| **Ag Pumping, Refrigeration, and Greenhouse Heat Curtain End Uses** | | | **172** | **$ 6,543,098** | **90%** |
| **AG Miscellaneous End Uses**** | | | **65** | **$ 749,951** | 10% |
| **AEEI PROGRAM TOTAL** | | | **237** | **$ 7,293,049** | **100%** |

Data Source: 1997 PG&E Frozen MDSS Database - April 8, 1998
*PG&E MDSS Measure Codes
**The miscellaneous end uses are evaluated under Protocol Table C-9. They are not included in this evaluation.
***The numbers do not add up due to rounding.

## *2.1 Descriptions of Programs Covered by the Evaluation*

Measures rebated under the following programs were evaluated as part of this project.

### 2.1.1 The Retrofit Express Program

The RE program offered fixed rebates to nonresidential customers to retrofit their facilities' gas or electric energy-efficiency equipment from a pre-specified list of measures. The program covered a wide range of energy-saving measures in the lighting, air conditioning, motors, refrigeration, and food service end uses. Specific refrigeration measures included cooler or freezer, non-electric condensate evaporator and strip curtains.

Customers were required to submit proof of purchase with their applications in order to receive rebates. The program was marketed primarily to small- and medium-sized commercial, industrial, and agricultural customers. The maximum rebate amount, including all measure types, was $300,000 per account. No minimum amount was required to qualify for a rebate.

### 2.1.2 The Retrofit Efficiency Options Program

1997 agricultural sector customers participated in both the REO agricultural and refrigeration programs. The participation included five measures: pump repair, low-pressure sprinkler nozzles, sprinkler to micro-irrigation conversion, heat curtains (REO Ag Program), and oversized condensers (REO Refrigeration Program). PG&E representatives worked with customers to identify cost-effective improvements, with special emphasis on operation and maintenance measures for customers' facilities. Marketing efforts were coordinated among PG&E Divisions, emphasizing local planning areas with high marginal electric costs to maximize program benefits.

## *2.2 Description of Evaluation*

This impact evaluation covers all measures installed at agricultural accounts, as determined by the Marketing Decision Support System (MDSS) sector code, that were included under the RE and REO programs and for which rebates were paid during calendar year 1997. The impact evaluation results in both gross and net impacts and compares these estimates to the program design estimates.

As part of a retroactive waiver agreement with California Demand Side Management Advisory Group (CADMAC), PG&E is allowed to use a default net-to-gross ratio of 0.75 in return for conducting a telephone-survey based market effects study of four key market barriers for the AEEI pumping and pumping related end-use market segment. The results of the market effects study are presented in a separate report.

### 2.2.1 Objectives

The evaluation objectives, as originally stated in the Request for Proposal (RFP), were refined during the project initiation meeting and were further refined in discussions with the PG&E project manager. Those objectives are:

1. **Determine first-year gross and net impacts** (kW, kWh, and therms) for the Ag sector of PG&E's AEEI programs. The AEEI programs include Ag sector incentives paid under the RE program, the REO program, and the 1997 Advanced Performance Options (APO). The evaluation covered AEEI measures for which incentives were paid during calendar 1997 for the Ag pumping and related, refrigeration, and greenhouse heat curtain end-uses. The greenhouse heat curtain end-use savings were derived solely from greenhouse heat curtain measures. There were no participants from the APO program paid in 1997.

2. **Compare the evaluation results to PG&E's (ex ante) estimates** and explain discrepancies to support improvements in future ex ante estimates.
3. **Conduct a telephone-survey based market effects study of four key market barriers for the AEEI pumping and pumping related end-use market segment.** As part of a retroactive waiver agreement with CADMAC, PG&E was allowed to use a default net-to-gross ratio of 0.75 in return for conducting a telephone-survey based market effects study of four key market barriers for the AEEI pumping and pumping related end-use market segment. This study was augmented by a market characterization based upon PG&E's 1996 AEMS Market Effects study, SCE's 1996 Agricultural Sector Market Effects Study, and the experience of the evaluation project team. This study is presented under separate cover.
4. **Create a retention panel for the 1997 program** to allow follow-up persistence studies.
5. **Recommend improvements for future programs, evaluations, and the Protocols.**
6. **Assess equipment survival rates for equipment installed under the 1994 and 1995 Ag program.** Revisit sites to determine whether equipment identified in the original 1994 and 1995 retention panels was still installed. This study is reported under separate cover.
7. **Report results in accordance with Protocols and support AEAP process as requested**. This includes program reporting, completion of the Protocol tables required for CPUC filings, and support during the AEAP process.

### 2.2.2 Evaluation Results

The gross impact results from the evaluation are grouped by technology type to clearly illustrate the trends in participation. Each technology is defined by the measures (i.e., measure codes) offered by the programs. These technologies are then summarized into the pumping and related, refrigeration, and Ag other end-uses that pertain to the agricultural sector. Since these three end uses encompass 90% of the ex ante resource value for the agricultural sector, they are the end uses analyzed in this report. The remaining measures are reported under the requirements of Table C-9 of the Protocols and are not part of this report.

The net program impacts are reported in the format indicated above for the gross impacts. Net program impacts are the result of adjusting the gross program impacts for the behavioral responses of the population to which the program was offered. These behaviors are termed free-ridership and spillover. The free-ridership adjustment reduces the gross impact to compensate for program participants who would have implemented the measure without the program incentive (would have done it anyway). The spillover adjustment increases the gross impact to compensate for customers who installed energy-efficient measures because of the program, but without receiving the program incentive. In this evaluation, the net-to-gross ratio used to determine net program impacts (0.75) was set by a retroactive waiver.

In addition to reporting the impacts as assessed by the evaluation (ex post results), this report compares these results to the original program estimates (ex ante estimates) in the form of realization rates. The realization rates are simply the ratio of the ex post results to the ex ante estimates. Wherever realization rates diverge significantly from 1.0 (i.e., ex post equals ex ante), the evaluation team attempts to explain the reasons for differences between the ex ante estimates and the ex post values. Based on these explained differences, recommendations are made for improvements in the program design, the evaluation approach, or the Protocols. These recommendations are aimed at improving future realization rates.

### 2.2.3 Timing

The 1998 evaluation of the 1997 AEEI programs commenced in June 1998, completed the planning stages in October 1998, conducted data collection from September through December 1998, and completed the reporting phase in February 1999.

### 2.2.4 Role of the Protocols

The Protocols specify most aspects of the evaluation. They define minimum sample sizes, required precision, data collection techniques, acceptable analysis approaches, and formats for documenting and reporting results to the CPUC. The Protocol requirements may be modified through submission and approval of a retroactive waiver to CADMAC. A retroactive waiver was submitted (approved June 17, 1998) for the AEEI program evaluation. This waiver allows (1) the use of a net-to-gross ratio of 0.75 if a market effects study was conducted instead of a net-to-gross analysis, and (2) the use of simplified engineering analysis for the refrigeration and greenhouse end-uses. A second waiver was submitted (approved January 20, 1999) to allow designated units of measure that better fit the refrigeration and Ag other end uses. Section 6 of this report contains the entire approved waivers

## *2.3 Report Layout*

This report is divided into seven sections plus the supporting appendices. These are:

*Section 1. Executive Summary* –supplies a synopsis of the report findings.

*Section 2. Introduction* – summarizes the report, introduces the programs, and presents a synopsis of the evaluation.

*Section 3. Methodology* – presents the approach used to analyze the data and derive the results.

*Section 4. Evaluation Results* – presents the impact findings and discusses discrepancies between the ex post impacts and the ex ante estimates.

*Section 5. Recommendations* – discusses recommendations emanating from the evaluation.

*Section 6. CADMAC Waiver* – documents the two waivers that were approved by CADMAC for the 1997 AEEI programs.

*Section 7. Protocol Tables 6 and 7* – supplies the detailed Protocol Table data required to file the study with the CPUC.

*Appendix A. Engineering Detailed Computation Methods* – presents a detailed explanation of the engineering analysis summarized in the body of the report.

*Appendix B. Final On-site Instruments* – supplies the final field data collection instruments for completeness.

# 3. METHODOLOGY

This section first discusses the data sources used in the analysis, followed by the gross impact analysis methodology.

## *3.1 Data Sources*

The key element to obtaining high accuracy in any evaluation is maximum use of all available data sources. The Equipoise team evaluated all applicable data available from PG&E and industry sources.

### 3.1.1 Existing Data

The primary existing data sources were:

- The MDSS database for 1997 - This database contained information on the Retrofit Express (RE) and Retrofit Efficiency Options (REO) programs for all sectors. The agricultural sector information was used in the evaluation.
- PG&E Pump Test Database - This database contained information on pump tests conducted as part of the PG&E Energy Management Services program. Pump test information was assessed for 1992-1997.
- PG&E program design documentation.
- PG&E billing data for 1996, 1997, and part of 1998.

### 3.1.2 Collected Data

Additionally, information was gathered from the following data sources and data collection tasks:

- On-site pump tests for REO pump repair participants with previous known pump tests, and pump tests for a census of low-pressure sprinkler and micro-irrigation conversion sites.
- On-site audits for a census of the participants in all three end-uses.
- “Irrigation Pumping Plants” by Blaine Hanson, UC Irrigation and Drainage Specialist, University of California Irrigation Program, Davis, California, 1994.
- “Cutting Energy Costs for Pumping Irrigation Water”, Division of Agricultural Sciences, University of California, Leaflet 21188, February, 1981.
- “Energy Conservation for Commercial Greenhouses”, Northeast Regional Agricultural Engineering Service, Cooperative Extension, NRAES-3, Third revision, July, 1989.
- “Energy Savings Using Greenhouse Shading/Insulating Screens Report”, Submitted to the California Energy Commission, Contract #400-92-010, November, 1994.
- “Refrigeration and Air Conditioning”, Third Edition, Air-Conditioning and Refrigeration Institute, Prentice-Hall, 1998.

- Appendix A, Thermodynamic Property Tables, International Institute of Ammonia Refrigeration (IIAR), Ammonia Data Book, December, 1992,
- Appendix B, Ammonia Refrigeration Application Data, International Institute of Ammonia Refrigeration (IIAR), Ammonia Data Book, December, 1992,
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 1995 HVAC Applications Handbook.
- ASHRAE 1997 Fundamentals Handbook.
- ASHRAE 1998 Refrigeration Handbook.

The numbers of survey data points collected are shown in Exhibit 3.1. The analysis of the 1995 retention data points is covered in a separate report.

**Exhibit 3.1**
**Surveys Data Points Completed**

| Customer Type | AEEI Program | | | | 1995 Retention | Total |
|---|---|---|---|---|---|---|
| | Pumping | Refrig. | Heat Curtain | Total | | |
| On-Site Surveys | | | | | | |
| Participant Applications | 138 | 13 | 11 | 162 | 0 | 162 |
| 1995 Retention | 0 | 0 | 0 | 0 | 123 | 123 |
| **Total** | **138** | **13** | **11** | **162** | **123** | **285** |

The sample information, showing the population, sample frame, and final analysis sample sizes are shown below in Exhibit 3.2.

**Exhibit 3.2**
**Sample Summary**

| End Use | Population* | Sample Frame | | Final Analysis Sample | |
|---|---|---|---|---|---|
| | | On-Site | Metering | On-Site | Metering |
| Pumping and Related | 148 | 148 | 96 | 138 | 82 |
| Refrigeration | 13 | 13 | 0 | 13 | 0 |
| Greenhouse Heat Curtain | 11 | 11 | 0 | 11 | 0 |
| Total Participant | 172 | 172 | 96 | 162 | 82 |
| 1995 Retention | 126 | 126 | - | 123 | - |

*Participant sample was a census, population refers to application numbers

### 3.1.3 Sample Design

#### *3.1.3.1 Overview*

Data were collected via on-site surveys from a census of program participants. The data collected from these samples provided the information needed for the impact evaluation (i.e., engineering analysis for gross impact) models. The sampling plan for the PG&E agricultural evaluation, based on 1997 program participation data and experience in past evaluations, is presented in this section.

#### *3.1.3.2 AEEI Participant Sample Frame*

For this evaluation, the participant population for the AEEI program is small, and the entire population was needed to fulfill the sample sizes required by the Protocols. There was no nonparticipant sample frame used in this analysis.

#### *3.1.3.3 Relative Precision of Sample*

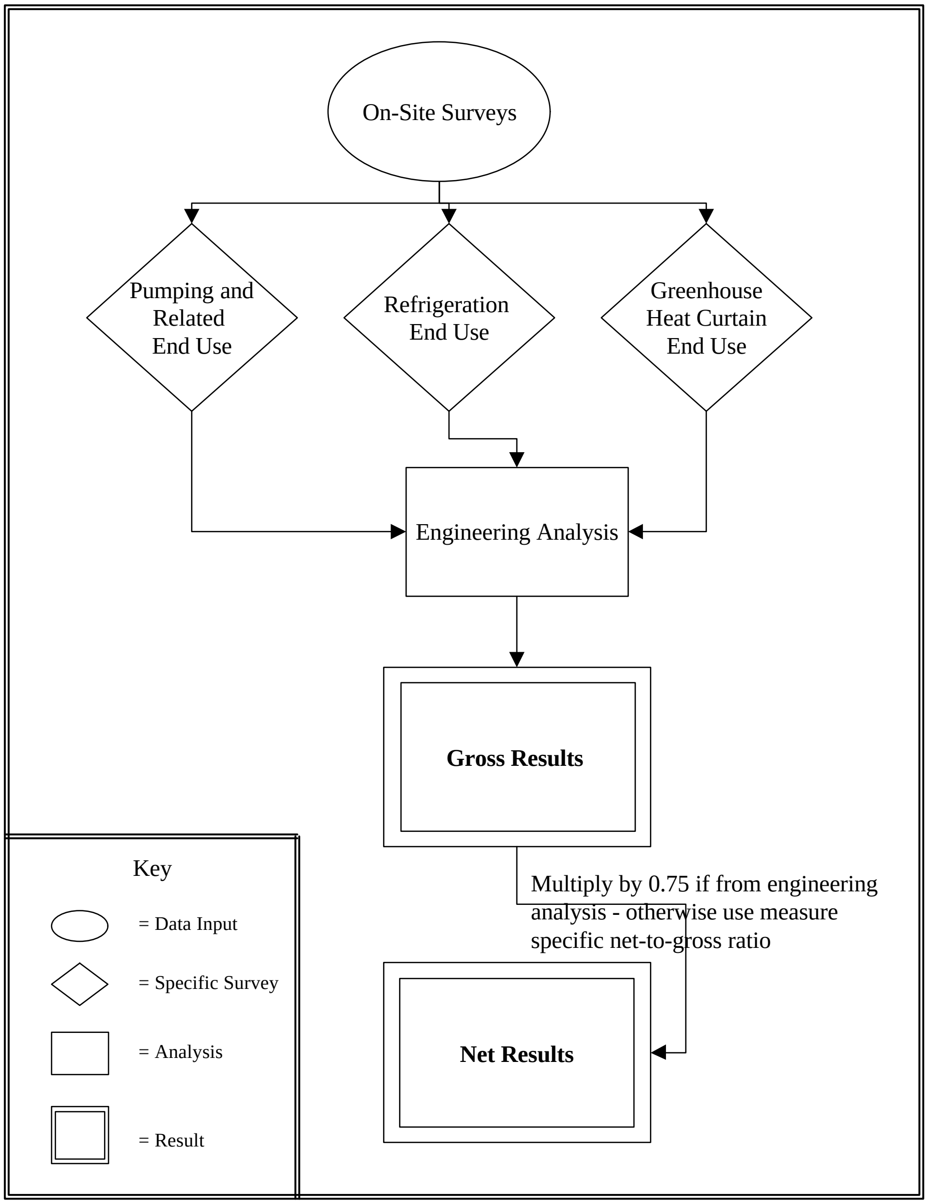
The relative precision of a given sample design based on total annual energy use reflects the uncertainty regarding the extent to which the allocated sample sizes are large enough to control for the population variance in terms of annual energy usage.

For AEEI participants, a census was attempted and there was no sampling to measure the extent to which the sample reflects the population.

## *3.2 Overview of Analysis*

The 1997 agricultural programs evaluation analyzed three end uses – Ag pumping and related, refrigeration, and Ag other (greenhouse heat curtains). A census of the applications had on-site audits performed to gather information for the engineering analyses that led to the gross impact results. A net-to-gross ratio of 0.75 was applied to all AEEI ex post gross impact estimates per the CADMAC waiver approved June 17, 1998. An overview of the impact method is shown in Exhibit 3.3. The ex ante net-to-gross ratio of the measures covered under the three end uses analyzed was also 0.75.

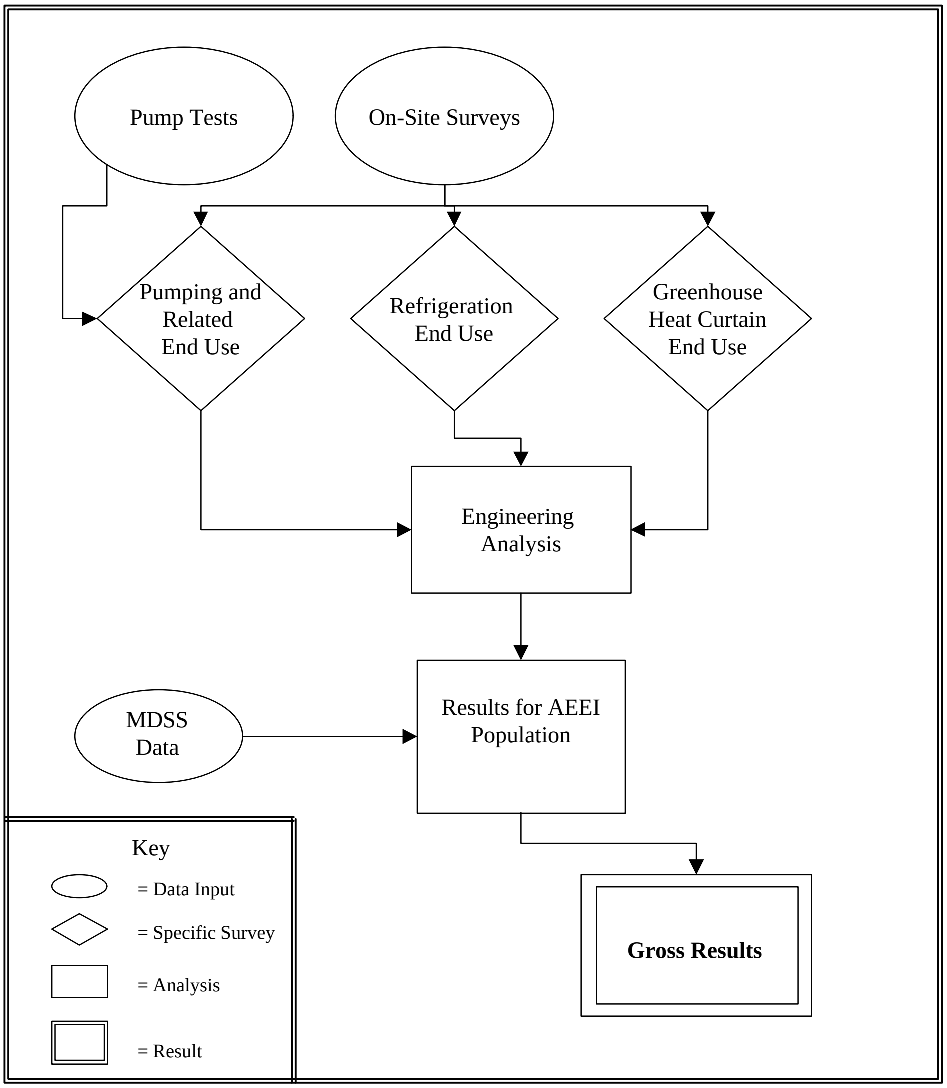
**Exhibit 3.3**
**Overview of Impact Method**




## *3.3 Gross Impact Analysis*

While a census of measures was audited on-site, the pumping and related end-use measures also collected data from pump tests performed during the evaluation. These pump tests were the core of the engineering analyses for this end use. The pump repair measure had pump tests performed for 30% of the paid applications. The micro-irrigation conversion applications averaged 1.5 pump tests per application, while the low-pressure sprinkler nozzle measure performed one pump test out of the five applications. Exhibit 3.4 shows the overview of the analysis of the gross impact.

**Exhibit 3.4**
**Gross Impact Overview**




### 3.3.1 Pumping and Related End Use

#### *3.3.1.1 Pump Repair*

There were 111 applications for this measure, representing 76 unique customers. In order for pump test results to identify the change in efficiency due to pump repairs, they must (1) be conducted both before and after the repair, and (2) be technically sound tests yielding good data. For example, if a well cannot be sounded for depth or does not have the proper length test section, the test gives poor and misleading results. The evaluation approach minimized evaluation cost yet continued to provide credible impact results for this measure by using the PG&E pump test database to select accounts carefully for post-repair pump tests. Only if the pump repair measure had a PG&E pump test performed before the repair, as determined from the pump test database, program applications, and discussions with the grower, was a post-installation pump test performed during the on-site audit. Analysis of the pump test database identified 48 pump tests that met those criteria. A census of these 48 pumps was attempted with 33 completed, good tests. For other pump repair sites, only retention and use information was collected.

The algorithm shown in Exhibit 3.5 was used to determine the energy impacts for pump repairs.

**Exhibit 3.5**
**Pump Repair Energy Impact Algorithm**

$$\text{Impact} = \sum_{i=1}^{111} \text{kWh}_{97,i} * \left(1 - \frac{\text{OPE}_{pre}}{\text{OPE}_{post}}\right)_i$$

Essentially, there were two pieces of information required to apply the impact algorithm to each pump repaired. First, the 1997 kWh for the site must be known for only the specific pump repaired. Second, the pump type and horsepower must be known to properly apply the second half of the algorithm – the OPE ratio.

On-site audits provided the information used to allocate the billing data usage. The horsepower of the other pumps on the meter and the percentage of time these pumps operated were gathered. Assuming the pumps were fully loaded when on, the percentage of the kWh used by the repaired pump was calculated. The audit also provided the horsepower and pump type for correct application of the OPE ratio.

The evaluation team collected post-repair OPE values from 33 pumps. These pumps had pre-repair OPE values already recorded in the PG&E pump test database. To increase the number of actual pre- and post-OPE paired values, the 1992-1997 PG&E pump test databases were analyzed to identify pumps with pre- and post-pump repair results. Since there is a difference in the paired pre-to-post efficiency possible based on technology (e.g., turbine, centrifugal, or axial flow pump), these data were analyzed by pump type. There was a large enough sample in the pump test database to separate the turbine pumps into two groups (bins) – 20-75 horsepower and over 75 horsepower.

Pump account number data were collected during the on-site audit to be able to pull the 1997 billing data. However, even with this information, there were eleven accounts with missing kWh data in 1997. For these pumps, the 1996 data was located and used to determine the impact.

The difference in kW pre- and post-repair was also analyzed using the 1992-1997 PG&E database information to determine if there were demand impacts. On average, there was an increase of 1.3 kW due to the pump repair. However, the standard deviation around that value was large and included zero. The pre- and post-repair kW values were further analyzed using a single-tailed t-test. At the 90% confidence level, there were no significant differences between the pre- and post-repair kW (t=0.001). Because of the results of the t-test, the demand impacts were set to zero for all the pump repair measures. This is consistent with the 1996 PG&E agricultural sector evaluation findings.

### *3.3.1.2 Low-Pressure Sprinkler Nozzles*

There were five sites rebated for this measure. The low-pressure sprinkler nozzle measure used an approach similar to the ex ante estimates, but used measured data from pump tests. The algorithms used for the demand impacts are shown in Exhibit 3.6.

**Exhibit 3.6**
**Low-Pressure Sprinkler Nozzles Demand Impact Algorithms**

(1) Delta hp = ($GPM_{\text{from pump test}}$) * delta TDH / (3960 GPM-Ft/hp* current OPE)
where TDH = total dynamic head
OPE = operating plant efficiency

(2) Delta hp / acre = (1) above / acres irrigated

(3) Nozzles / acre = nozzles found at site / acres irrigated

(4) Delta kW / nozzle = (2) above * 0.746 kW/hp / (3)

(5) Peak kW / nozzle impact = (4) above * Coincident Diversity Factor of 0.78[1]

Certain assumptions were made during the low-pressure sprinkler nozzle analysis. It was assumed that the OPE of the old and new systems was the same if there was no change in the pumping system. If the pump had been retrofitted, the pre-OPE was determined based on information from the pump repair analysis. It was assumed that the irrigation efficiency (IE) of the old system and the new system was the same. Therefore, there was no assumed difference between the acre-feet (AF) of water pumped in 1997 and what would have been pumped with the old high-pressure sprinkler system. These assumptions result in conservative estimates. The nozzle pressure (shown as “P” in Exhibit 3.7) in pounds per square inch (psi) for the pre- and post-nozzles was based on grower self-reports. The algorithms used to determine site-specific energy impacts for the low-pressure sprinkler systems are shown in Exhibit 3.7.

[1] Appendix A of “Impact Evaluation of Pacific Gas & Electric Company’s 1995 Agricultural Energy Efficiency Incentive Programs: Pumping and Related End-use, Indoor Lighting End-use. PG&E Study ID Numbers: 329: Pumping and Related End-use. 331: Indoor Lighting End-use”, Dated March 1, 1997.

**Exhibit 3.7**
**Low-Pressure Sprinkler Nozzle Energy Impact Algorithms**

(1) Post-total dynamic head (TDH) from nozzles = $P_{post}$ (psi) * 2.31 ft/psi

(2) Post-TDH other than nozzles = Actual TDH from pump test – (1) above

(3) Pre-TDH = $P_{pre}$ (psi) * 2.31 ft/psi + (2) above

(4) AF = 1997 kWh / $(kWh/AF)_{from\ pump\ test}$

(5) kWh / AF $_{pre}$ = 1.0241 * (3) above / OPE $_{pre}$

(6) kWh $_{pre}$ = (4) above* (5) above

(7) kWh Impact = kWh 1997 – (6) above

(8) kWh / nozzle impact = (7) above / nozzles installed

*3.3.1.3 Micro-irrigation Conversion*

The participants for this measure represented 32 applications and 14 unique customers.

For the demand impacts, the micro-irrigation conversion measure used an approach similar to the low-pressure sprinkler nozzle analysis. The on-site audits determined whether the system ran during peak periods. A coincident diversity factor (CDF) was applied on a site-specific basis. If the site ran 24 hours per day during watering sets, the CDF was set to one. If it was determined that there was a peak period lock out on the metering box or the irrigation sets were for 12 hours or less, the CDF was set to zero. The average CDF for the 32 sites was 0.87.

**Exhibit 3.8**
**Micro-irrigation Conversion Demand Impact Algorithms**

(1) Delta TDH = Pre TDH – Post TDH

(2) kW Impact = (GPM $_{from\ pump\ test}$) * (1) above / (3960 GPM ft/hp* post OPE) * 0.746 kW/hp * CDF

(3) kW Impact / acre = (2) above / acres converted

Micro-irrigation system conversion rebates were paid when a customer converted from a sprinkler irrigation system (either high-pressure or low-pressure) to a micro-irrigation system. There was one site that converted from a flood irrigation system. The demand and energy impacts at this site were set to zero.

In general, the pumping systems were renovated to allow the micro-irrigation to function properly. The impact of the retrofit both decreased the AF of water applied and changed the pumping system. The analysis of the micro-irrigation sites used the pump test information in a similar fashion to the low-pressure sprinkler nozzle analysis. The estimated pre- and post-pressures were based on grower self-reports.

Questions were asked in the field regarding the previous irrigation system type. The irrigation efficiency value used to determine the AF/year that would have been applied without the micro-irrigation system was determined from two sources: (1) previous Ag evaluation data (irrigation efficiency results for sprinkler systems) and (2) an estimate of the current systems' irrigation efficiency as determined by the experts in the field (and referenced with any current research). Taking these two sources into account, the analysis used a 10% increase in the irrigation efficiency between the pre- and post-retrofit irrigation system.

When a pump was replaced with a different type, the pre-OPE assigned to the pump was based on the previous pump type. For example, if the post-retrofit pump was a turbine booster and the pre-retrofit pump had been a centrifugal pump, the average OPE for "routine" tests within the PG&E pump test database was applied for the pre-retrofit OPE. The on-site audit determined if the post-retrofit pump had been repaired. If so, the OPE difference was based on the pump repair analysis OPE ratio. The site-specific energy impact algorithms are shown in Exhibit 3.9.

**Exhibit 3.9**
**Site-Specific Micro-irrigation Energy Impacts**

(1) Post-total dynamic head (TDH) from system = $P_{post}$ (psi) * 2.31 ft/psi

(2) Post-TDH outside of micro system = Actual TDH from pump test – (1) above

(3) Pre-TDH = $P_{pre}$ (psi) * 2.31 ft/psi + (2) above

(4) $AF_{post}$ = 1997 kWh / $(kWh/AF)_{from\ pump\ test}$

(5) $AF_{pre}$ = $AF_{post}$ * post IE / pre IE

(6) kWh / $AF_{pre}$ = 1.0241 * (3) above / pre OPE

(7) $kWh_{pre}$ = (5) above * (6) above

(8) kWh Impact = $kWh_{pre}$ – $kWh_{post}$

(9) kWh / Acre Impact = (8) above / Acres converted

In a few cases, the system obtained irrigation water from more than one pump. Information was gathered during the on-sites to determine the total acres covered by the micro-irrigation system and the pumps/accounts that fed that system.

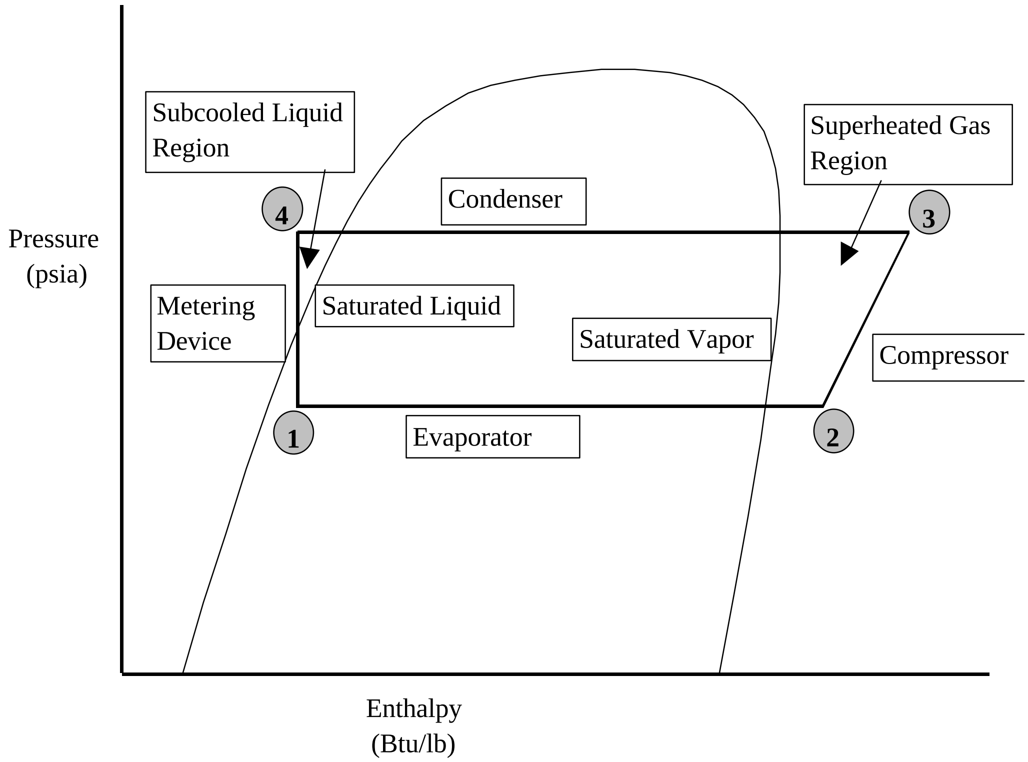
### 3.3.2 Refrigeration End Use

There were three distinct analyses performed for the refrigeration measures. Ten of the thirteen measures paid during 1997 within the refrigeration end use were for oversized condensers . Of these ten oversized condensers, nine were installed on ammonia systems and the remaining measure was on a halogenated hydrocarbon system. There were two non-electric evaporative condensers on refrigerator/freezer measures and one strip curtain measure. The analysis performed on the oversized condensers will be discussed first.

#### *3.3.2.1 Oversized Condensers*

To understand how this measure was analyzed, a short explanation of a typical refrigeration process is presented. Within a standard refrigeration system there are four distinct pieces of equipment: a condenser, a metering device, an evaporator, and a compressor. Exhibit 3.10 shows a typical pressure-enthalpy (enthalpy is the heat content of a refrigerant) diagram for a refrigeration system. Each piece of equipment is shown on this diagram based upon where it is used in the refrigeration cycle. The refrigerant goes through four stages, as represented by the four numbers in circles in the diagram. Each stage will be discussed.

**Exhibit 3.10**
**Pressure-Enthalpy Diagram**




At point 1, the refrigerant is a mixture of liquid and gas. As the refrigerant moves through the evaporator, it maintains the same pressure and absorbs heat from the space being cooled. The heat causes the liquid portion to boil and become a gas. The curved line on the right side of the diagram represents the point where the liquid phase ceases to exist and the vapor becomes fully saturated. After the refrigerant gets hotter than the saturated vapor state, it is a superheated vapor. Moving from point 1 to point 2, the enthalpy is steadily increasing, as shown in the diagram.

At point 2, the refrigerant is now a superheated gas as it enters the compressor. The compressor increases the pressure of the gas and adds some heat due to the compression (heat of compression). The impacts from the installed measure are realized at the compressor as the oversized condenser decreases the pressure to which the compressor must raise the refrigerant. (i.e., as the refrigerant moves from point 2 to point 3).

From point 3, the refrigerant goes through the condenser. In the condenser, it steadily gives up heat to the atmosphere and condenses from a gas to a liquid. The condenser generally continues to cool refrigerant past the point where all of the gas becomes a liquid (the saturated liquid line). The refrigerant is now a sub-cooled liquid at point 4.

The refrigerant then moves through a metering device (often referred to as an expansion valve) from point 4 back to point 1. This device decreases the pressure, but keeps the same amount of heat (enthalpy) within the refrigerant. The refrigeration cycle is complete.

This short rendition of a refrigeration cycle does not take into account the real-world losses associated with any type of refrigeration cycle. It assumes perfect (isentropic) compression and perfectly functioning pieces of equipment. These assumptions were used in the analysis.

The kW impact for this measure was determined as shown in Exhibit 3.11.

**Exhibit 3.11**
**Refrigeration Demand Impact Algorithm**

$$\text{kW} = \frac{\text{Work of Compression} * \text{Mass Flow} * \text{Tons of Refrigeration} * \text{Conversion from Btu/hr to kW}}{\text{Efficiency of Motor}}$$

$$\text{kW} = \frac{\frac{\text{Btu}}{\text{lb}} * \frac{\text{lb}}{\text{hr - ton}} * \text{tons} * \frac{1\,\text{kW}}{3413\,\text{Btu/hr}}}{h}$$

The average kW reduction for a specific refrigeration load was determined and the hours of operation were applied to determine the kWh impacts, as shown in Exhibit 3.12. The hours of operation were gathered on site from the plant manager.

**Exhibit 3.12**
**Refrigeration Energy Impact Algorithm**

$$\text{kWh savings} = \sum_{i=1}^{n} \text{kW impact}_i * \text{Hours of operation}_i$$

*3.3.2.2 Non-Electric Condensate Evaporator Refrigerators/Freezers*

There were two sites that installed this measure. One installed just a refrigerator while the other installed both a refrigerator and freezer. The make and model numbers were gathered on site and the manufacturers of the equipment were contacted to determine if the condensate evaporator was actually non-electric. The ex ante estimate of impact was used for the ex post impacts of this measure.

*3.3.2.3 Strip Curtains*

One site installed strip curtains. Data were collected during an on-site audit to determine how the strip curtain was installed and used. Information from the plant manager was used to analyze the data for possible impacts. A custom analysis based on standard thermodynamic heat transfer analysis techniques was applied to this site. This analysis can be found in Appendix D and a discussion of the reasons for the ex post impact estimates can be found in Section 4.4.2.3.

### 3.3.3 Greenhouse Heat Curtain End Use

There were eleven applications for greenhouse heat curtains paid in 1997. The applications represent nine different customers. All greenhouses were audited for this evaluation.

The greenhouses were constructed of many different materials, from glass to fiber-reinforced polyester to polyethylene film. The majority of the sites were multi-span buildings with many peaks. The heat curtains were installed to reduce the therm usage of natural gas heaters by minimizing the heated area and decreasing heat loss from the greenhouses at night. However, while nighttime heating savings were planned, the heat curtains were also used during the day to control day length, shade crops, and reduce daytime temperatures within the greenhouse.

The curtains were thin, movable, and attached to the greenhouse using various mechanisms. Research indicated that, in many areas of the U.S., 80% of the energy for heating of single-glazed structures is required at night.[2] Therefore, insulation that can allow for daytime sunlight and reduce nighttime heat loss should be moveable. The heat curtain measure, as implemented by PG&E, required the inclusion of tracks and a motor to deploy the heat curtain . All heat curtains met this requirement.

The heat curtains were most often placed at a slight upward angle into the middle of the peak from the join between the roof and wall. When closed, the curtain created a “new” ceiling which was lower.

While the curtains were sometimes deployed during the day, most of the actual therm energy impacts occurred at night. The impacts were dependent on the construction of the building, the infiltration of cold air into the greenhouse, how the heat curtain was installed, and the efficiency of the natural gas heater. Based on previous experience, the determination of the efficiency of heaters in greenhouses can be quite difficult. Therefore, for this evaluation, the efficiency was set at 70% for either individual heaters in the greenhouses or a central boiler. This efficiency is lower than the minimum efficiency (75% for central steam boiler and 74% for unit heaters) set by the California Energy Commission (CEC) and accounts for the age of the units and piping losses. The actual temperatures required in the greenhouses were dependent on the crop. The impacts for heat curtains were determined using the algorithms shown in Exhibit 3.13 and Exhibit 3.14.

[2] Energy Conservation for Commercial Greenhouses, Northeast Regional Agricultural Engineering Service, NRAES-3, July, 1989.

**Exhibit 3.13**
**Heat Curtain Impact Algorithm**

$$\Delta Therms = \frac{\Delta Q_t * AnnualHrs * C1}{h}$$

Where:

| | | |
|---|---|---|
| $\Delta Q_t$ | = | Change in heat loss, Btu/hr |
| Annual Hrs | = | Annual Hours in Use, hr |
| C1 | = | Conversion for Therms, 1 therm/100,000 Btu |
| $\eta$ | = | Efficiency of heater, unitless |

The change in the heat loss of the greenhouses due to the addition of the heat curtain ($Q_t$) was determined by both the heat loss due to conduction (heat migrating through the materials from the higher temperature inside to the lower temperature outside) and the heat loss due to infiltration (heat loss through open areas in the construction). These two heat losses were determined as shown below in Exhibit 3.14.

**Exhibit 3.14**
**Heat Loss Algorithm**

$$\Delta Qt = \left[\left(\sum_{i=1}^{n} U_i * A_i\right) * CM + c_p * Vol * ACH\right]_{pre} * \Delta T - \left[\left(\sum_{i=1}^{n} U_i * A_i\right) * CM + c_p * Vol * ACH\right]_{post} * \Delta T$$

Where:

| | | |
|---|---|---|
| $U_i$ | = | Heat transfer coefficient of each material *i*, Btu/hr-ft$^2$-°F |
| $A_i$ | = | Area of each material *i*, ft$^2$ |
| CM | = | Construction Multiplier based on frame type, unitless |
| $\Delta T$ | = | Average inside to outside temperature difference, °F |
| $c_p$ | = | volumetric specific heat of air, 0.018 Btu/ ft$^3$-°F |
| Vol | = | Volume of the greenhouse, ft$^3$ |
| ACH | = | Air changes per hour, changes/hr |

The impacts determined were site specific and, in some cases, greenhouse specific.

## *3.4 Net-to-Gross Analysis*

### 3.4.1 Waiver Discussion

At the beginning of the 1997 agricultural sector evaluation, PG&E submitted a waiver to CADMAC covering methods to be used in the evaluation. This waiver is presented for completeness in Section 6. One of the elements of the waiver was a proposal that PG&E be allowed to use a "net-to-gross ratio of 0.75 for the agricultural sector, subject to the condition that PG&E conduct a telephone-survey based market effects study of four key market barriers for the pumping and pumping related end use. This waiver was approved by CADMAC on June 17, 1998. The market effects study will be reported under separate cover by March 30, 1999, as specified in the waiver.

## *3.5 Integration of Net-and-Gross Estimates*

The gross impacts were simply multiplied by the net-to-gross ratio of 0.75 to determine the net impact results.

# 4. EVALUATION RESULTS

## *4.1 Gross Impacts*

The gross impacts are shown in Exhibit 4.1.

**Exhibit 4.1**
**Gross Impacts**

| End Use | PG&E Code * | Measure Description | N App. | Ex Post Gross Impacts | | |
|---|---|---|---|---|---|---|
| | | | | kWh | kW | Therms |
| **Ag Pumping and Related** | A1 | Pump Repair | 111 | 4,672,255 | - | - |
| | A40 / A41 / A42 / A43 | Low-Pressure Nozzles | 5 | 93,920 | 40 | - |
| | A44 / A45 / A47 / A49 / A51 / A55 | Micro-Irrigation Conv. | 32 | 1,167,915 | 1,411 | - |
| | **Ag Pumping and Related End Use Total** | | 148 | 5,934,091 | 1,451 | - |
| **Refrigeration** | R17 / R18 | High-Capacity Condenser | 10 | 2,548,252 | 285 | - |
| | R2 | Strip Curtains for Walk-In | 1 | - | - | - |
| | R52 | Condensate Evaporator | 2 | 1,681 | 0.1 | - |
| | **Refrigeration End Use Total** | | 13 | 2,549,933 | 285 | - |
| **Greenhouse Heat Curtain Total** | A10 | Greenhouse Heat Curtain | 11 | - | - | 380,118 |
| **Ag Pumping, Refrigeration, and Greenhouse Heat Curtain End Uses** | | | **172** | **8,484,024** | **1,736** | **380,118** |
| **AG Miscellaneous End Uses**** | | | **65** | **1,763,304** | **301** | **-** |
| **AEEI PROGRAM TOTAL** | | | **237** | **10,247,327** | **2,037** | **380,118** |

Data Source: 1997 PG&E Frozen MDSS Database - April 8, 1998
*PG&E MDSS Measure Codes
**The miscellaneous end uses are evaluated under Protocol Table C-9. They are not included in this evaluation.

The differences between the ex ante and ex post gross impacts are discussed below in section 4.4.

## *4.2 Net-to-Gross Adjustments*

The gross impacts were multiplied by 0.75 to determine the net impacts, as per the CADMAC Waiver approved on June 17, 1998.

## *4.3 Net Impacts*

The net impacts are shown in Exhibit 4.2.

**Exhibit 4.2**
**Net Impacts**

| End Use | PG&E Code * | Measure Description | N App. | Ex Post Net Impacts | | |
|---|---|---|---|---|---|---|
| | | | | kWh | kW | Therms |
| **Ag Pumping and Related** | A1 | Pump Repair | 111 | 3,504,191 | - | - |
| | A40 / A41 / A42 / A43 | Low-Pressure Nozzles | 5 | 70,440 | 30 | - |
| | A44 / A45 / A47 / A49 / A51 / A55 | Micro-Irrigation Conv. | 32 | 875,937 | 1,058 | - |
| | **Ag Pumping and Related End Use Total** | | 148 | 4,450,568 | 1,088 | - |
| **Refrigeration** | R17 / R18 | High-Capacity Condenser | 10 | 1,911,189 | 214 | - |
| | R2 | Strip Curtains for Walk-In | 1 | - | - | - |
| | R52 | Condensate Evaporator | 2 | 1,261 | 0.1 | - |
| | **Refrigeration End Use Total** | | 13 | 1,912,450 | 214 | - |
| **Greenhouse Heat Curtain Total** | A10 | Greenhouse Heat Curtain | 11 | - | - | 285,088 |
| **Ag Pumping, Refrigeration, and Greenhouse Heat Curtain End Uses** | | | **172** | **6,363,018** | **1,302** | **285,088** |
| **AG Miscellaneous End Uses**** | | | **65** | **1,482,983** | **250** | **-** |
| **AEEI PROGRAM TOTAL** | | | **237** | **7,846,001** | **1,552** | **285,088** |

Data Source: 1997 PG&E Frozen MDSS Database - April 8, 1998
*PG&E MDSS Measure Codes
**The miscellaneous end uses are evaluated under Protocol Table C-9. They are not included in this evaluation.

There was no net analysis to determine the net-to-gross ratio. Therefore, all the discussion regarding the evaluation differences between the ex ante estimates and ex post results are in section 4.4, Gross Realization Rates.

## *4.4 Gross Realization Rates*

The evaluation gross realization rates are shown in Exhibit 4.3. The discrepancies will be discussed by end use and measure.

**Exhibit 4.3**
**Gross Realization Rates**

| End Use | PG&E Code * | Measure Description | N App. | Gross Realization Rates kWh | kW | Therms |
|---|---|---|---|---|---|---|
| **Ag Pumping and Related** | A1 | Pump Repair | 111 | 1.28 | 0.00 | - |
| | A40 / A41 / A42 / A43 | Low-Pressure Nozzles | 5 | 0.66 | 0.76 | - |
| | A44 / A45 / A47 / A49 / A51 / A55 | Micro-Irrigation Conv. | 32 | 0.24 | 0.57 | - |
| | **Ag Pumping and Related End Use Total** | | 148 | 0.69 | 0.44 | - |
| **Refrigeration** | R17 / R18 | High-Capacity Condenser | 10 | 1.07 | 0.69 | - |
| | R2 | Strip Curtains for Walk-In | 1 | 0.00 | 0.00 | - |
| | R52 | Condensate Evaporator | 2 | 0.33 | 0.33 | - |
| | **Refrigeration End Use Total** | | 13 | 1.07 | 0.69 | - |
| **Greenhouse Heat Curtain Total** | A10 | Greenhouse Heat Curtain | 11 | - | - | 0.65 |
| **Ag Pumping, Refrigeration, and Greenhouse Heat Curtain End Uses** | | | **172** | **0.77** | **0.47** | **0.65** |
| **AG Miscellaneous End Uses**** | | | **65** | **1.00** | **1.00** | **-** |
| **AEEI PROGRAM TOTAL** | | | **237** | **0.80** | **0.51** | **0.65** |

Data Source: 1997 PG&E Frozen MDSS Database - April 8, 1998
*PG&E MDSS Measure Codes
**The miscellaneous end uses are evaluated under Protocol Table C-9. They are not included in this evaluation.

## 4.4.1 Pumping and Related End Use

### *4.4.1.1 Pump Repair*

The ex ante and ex post impacts were determined using the algorithm shown in Exhibit 3.5 and 1996 billing data. The total ex ante kWh billed from the MDSS was 34,768,389 kWh for the 111 pumps repaired. This value represents the pre-repair pump usage for only the repaired pumps. Once the 1997 kWh data were analyzed to obtain the post-repair pump usage for the repaired pumps, it totaled 25,607,561. The decrease in usage from 1996 was expected due to the wet weather in 1997. Based on this alone, one would expect the ex post impact to be smaller than the ex ante estimate. This was not the case because of the higher than projected OPE ratios determined in the ex post analysis and applied for all pumps. The ex ante analysis used two horsepower bins to determine OPE and did not distinguish between pump types. For comparison purposes only, Exhibit 4.4 compares the OPE values used for the ex ante and the ex post cases in the bins used in the ex ante estimates. These are not the bins used in the ex post analysis; however, Exhibit 4.4 does demonstrate that the ex post OPE values are higher than the ex ante OPE estimates. The OPE ratio differences were the reason for the ex post impacts being higher than the ex ante estimate of impacts.

**Exhibit 4.4**
**Ex Ante and Ex Post OPE Ratios**

| | Bin 1 (20-75 hp) | Bin 2 (Over 75 hp) |
|---|---|---|
| Ex Ante | 0.210 | 0.106 |
| Ex Post | 0.230 | 0.181 |
| N of Ex Post | 55 | 56 |

*4.4.1.2 Low-Pressure Sprinkler Nozzles*

The evaluation team audited four of the five sites. The impacts for two of the sites were set to zero. One of the two sites was using the nozzles for flow regulation and had not decreased pressure at the pump. The other site increased both the horsepower and the pressure seen at the pumps, while moving from watering with four sets of nozzles to three sets of nozzles. While the grower was able to water the same acreage in less time, there were no kW or kWh impacts to PG&E.

One site had good pump test information. The algorithms shown in Exhibit 3.6 and Exhibit 3.7 were applied to the data collected at this site. This site had a realization rate higher than 1.0. It was because of this site that the overall realization rate for this measure was higher than 0.50 (e.g., if two sites have a realization rate of 0 and the other two have a realization rate of 1.0, the average would be 0.50).

Because only one site had both a positive impact and pump test data available, and the realization rates were over 1.0 for that site, the results of that one site were not used to help determine the impacts of the two sites without data. The ex ante estimates were conservatively used for the two sites where pump test data could not be collected. For one of these two sites, the grower was contacted only after many attempts. He indicated that the sprinkler system could not be tested. The grower was reluctant to give further information. The findings during the on-site audit at the non-zero/non-tested site indicated that there were impacts at the pump, but no pump test could be performed.

*4.4.1.3 Micro-irrigation Conversion*

The thirty-two sites with micro-irrigation conversion rebates showed a much lower ex post energy impacts than predicted by the ex ante estimates. It was not possible to collect good pump test data for all sites. There were six sites to which the average of the other 26 ex post analyses results of kWh/acre (202 kWh/acre) and kW/acre (0.18 kW/acre) impacts were assigned.

The ex post kWh impact is smaller than the ex ante estimate due to lower ex post findings for the acre-foot per acre (AF/Ac) of water applied and the lower pre/post pressure difference. The ex ante estimate assumes an average 2.7 AF/Ac, while the ex post average finding was 1.3 AF/Ac. The ex ante estimate uses an acreage-weighted, average annual net irrigation requirement with various assumptions such as 33% of average annual gross rainfall as effective. The ex post findings used the 1997 kWh data for all pumps irrigating the acreage and kWh/AF from the site-specific pump test to determine the AF used on the crop in 1997. The AF value was then divided by the acreage watered by micro-irrigation to determine the AF/Ac value.

The ex ante assumed a pressure difference of 36 psi between the pre- and post-retrofit systems, while the actual average ex post pressure difference found for the sites inspected was only 13 psi. Coupled with the lower AF/Ac value, the ex post energy impact was substantially lower than the ex ante estimate. The lower pressure difference also led to a lower ex post demand impact.

### 4.4.2 Refrigeration End Use

#### *4.4.2.1 Oversized Condensers*

The ex post energy impacts for oversized condensers were higher than the ex ante estimates, while the demand impacts were lower. The ex post analysis resulted in a lower tons of compression total heat rejected (THR). The ex ante average value was 789 tons THR, while the ex post average finding was 351 tons THR. However, the ex post estimated full load operating hours were higher (4,571 ex post versus 3,030 ex ante). Additionally, the ex post analysis had a slightly greater condensing temperature difference pre-to-post than the ex ante (15.1 ex post versus 11.3 ex ante), leading to greater impacts.

The differences were not surprising since the evaluation used the actual average operating pressures found at each site to determine the tons of refrigeration used, while the ex ante estimate used the maximum possible tons of heat rejection between the pre- and post-retrofit estimate at design temperatures. These findings also explain why the ex post demand impacts are less than the ex ante estimates.

#### *4.4.2.2 Non-Electric Condensate Evaporator Refrigerators/Freezers*

There were two sites that installed this measure. One installed only a refrigerator, while the other installed both a refrigerator and freezer. At the site with just the refrigerator, the manufacturer used air funneled around the compressor to defrost the evaporator. The ex ante estimate was used for the ex post impact result. At the other site, the manufacturer used electric resistant coils to defrost. A technical engineer at this manufacturer was queried specifically regarding what they used. It was determined that the defrosting device drew about 300 watts and there are no models that use hot gas to defrost. Therefore, the impacts were set to zero for this site (for both the refrigerator and freezer). Since the measure impacts are the same, regardless of whether the measure was a refrigerator or a freezer, the ex post results are simply one-third of the ex ante estimates.

#### *4.4.2.3 Strip Curtains*

One site installed strip curtains. This site did not use the strip curtains as expected in the ex ante estimate. The ex ante estimates assumed that strip curtains are placed between a refrigerated walk-in and a conditioned space. At this site, the strip curtains were placed on a large door between the outside and an unconditioned warehouse. The warehouse shared interior walls with refrigerated storage space. The curtains were installed to decrease the wind through the space and decrease the temperature within the unconditioned warehouse. Once the plant manager realized that he could refrigerate the warehouse space in the evenings, he used it about three times per week to store excess produce. The unconditioned warehouse was brought down to 34° F by closing all outside doors and opening up large doors between the refrigerated and unconditioned spaces. The site operator stated that the strip curtains made this possible because they kept the daytime temperature in the previously unconditioned space lower. The site operator stated that without the measure he would not have been able to use the previously unconditioned space in this manner.

Based on assumptions within the analysis of this site and how the space was used during 1997, the impacts from the installation of the strip curtains were equal to or less than the energy used to refrigerate the unconditioned warehouse. The ex post impacts were set to zero.

### 4.4.3 Greenhouse Heat Curtain End Use

The ex post findings of impacts were less than the ex ante estimate of impacts. The ex ante estimate of impacts used an average savings of 0.60 therms per square foot of heat curtain purchased. The ex post analysis average impacts were 0.50 therms per square foot of heat curtain installed. Included in the therms/$ft^2$ value are all the differences between the ex ante and ex post analysis method and input assumptions. Some of these inputs are shown in Exhibit 4.5. These include a lower average nighttime temperature, a smaller reduction in air changes, differences in roof U-values, and fewer square feet of heat curtain installed than was originally rebate.

**Exhibit 4.5**
**Ex Ante and Ex Post Heat Curtain Inputs**

| Input Item | Ex Ante | Ex Post |
|---|---|---|
| Nighttime Temperature | 65 °F | Varied between 45 °F and 85 °F with an average of 60 °F |
| Air Changes with Heat Curtain | 33% reduction | 12% reduction |
| Roof U-value No Heat Curtain | 1.23 | 1.02 |
| Roof U-value With Heat Curtain | 0.45 | 0.50 |

The ex post impacts averaged 38% of the pre-retrofit estimated therm usage. While the pre/post-therm usage could not be correlated with billing data reductions because many sites had multiple greenhouses on one meter, billing data were looked at for some of the sites. The estimated usage for a few of the specific greenhouses was not unreasonably large or small compared to the actual therm usage. As such, while the gross realization rate was relatively low, the evaluation team believes the analysis appropriately reflects the actual impacts.

## *4.5 Net Realization Rates*

Since the net-to-gross ratios were the same for the ex ante and the ex post measures, the net realization rates are identical to the gross realization rates. For the sake of completeness, however, they are shown in Exhibit 4.6.

### Exhibit 4.6
### Net Realization Rates

| End Use | PG&E Code * | Measure Description | N App. | Net Realization Rates kWh | kW | Therms |
|---|---|---|---|---|---|---|
| **Ag Pumping and Related** | A1 | Pump Repair | 111 | 1.28 | 0.00 | - |
| | A40 / A41 / A42 / A43 | Low-Pressure Nozzles | 5 | 0.66 | 0.76 | - |
| | A44 / A45 / A47 / A49 / A51 / A55 | Micro-Irrigation Conv. | 32 | 0.24 | 0.57 | - |
| | **Ag Pumping and Related End Use Total** | | 148 | 0.69 | 0.44 | - |
| **Refrigeration** | R17 / R18 | High-Capacity Condenser | 10 | 1.07 | 0.69 | - |
| | R2 | Strip Curtains for Walk-In | 1 | 0.00 | 0.00 | - |
| | R52 | Condensate Evaporator | 2 | 0.33 | 0.33 | - |
| | **Refrigeration End Use Total** | | 13 | 1.07 | 0.69 | - |
| **Greenhouse Heat Curtain Total** | A10 | Greenhouse Heat Curtain | 11 | - | - | 0.65 |
| **Ag Pumping, Refrigeration, and Greenhouse Heat Curtain End Uses** | | | **172** | **0.77** | **0.47** | **0.65** |
| **AG Miscellaneous End Uses**** | | | **65** | **1.00** | **1.00** | **-** |
| **AEEI PROGRAM TOTAL** | | | **237** | **0.81** | **0.51** | **0.65** |

Data Source: 1997 PG&E Frozen MDSS Database - April 8, 1998
*PG&E MDSS Measure Codes
**The miscellaneous end uses are evaluated under Protocol Table C-9. They are not included in this evaluation.

## *4.6 Gross Per-Unit Impacts*

The gross per-unit impacts are shown in Exhibit 4.7.

### Exhibit 4.7
### Gross Per-Unit Impacts

| End Use | Measure Description | DUOM | N of DUOM Electric | Gas | Ex Post Gross Per-Unit Impacts kWh | kW | Therms |
|---|---|---|---|---|---|---|---|
| **Ag Pumping and Related** | Pump Repair | AF of Water Pumped | 95,944 | - | 49 | 0.000 | - |
| | Low-Pressure Nozzles | | 10,321 | - | 9 | 0.004 | - |
| | Micro-Irrigation Conv. | | 4,770 | - | 245 | 0.296 | - |
| | **Ag Pumping and Related End Use Total** | | 111,035 | - | 53 | 0.013 | - |
| **Refrigeration** | High-Capacity Condenser | Tons of Refrigeration (THR) | 3,512 | - | 726 | 0.081 | - |
| | Strip Curtains for Walk-In | | 0 | - | 0 | 0.000 | - |
| | Condensate Evaporator | | 49 | - | 34 | 0.002 | - |
| | **Refrigeration End Use Total** | | 3,561 | - | 716 | 0.080 | - |
| **Greenhouse Heat Curtain Total** | Greenhouse Heat Curtain | Square Foot of Heat Curtain | 0 | 789,069 | - | - | 0.48 |

The filed Table E3 produced by PG&E used a designation unit of measure (DUOM) of the number of applications for the refrigeration and Ag other end-uses. As such, the per-unit savings are not directly comparable to ex ante estimates, as shown in Exhibit 4.7. However, if the ex post gross impacts are divided by the number of applications (13 for refrigeration and 11 for Ag other), the per-unit impacts can been directly compared . These direct comparisons of per-unit impacts are shown in Exhibit 4.8.

For the pumping and related end use, the ex ante per-unit estimate (shown in Exhibit 4.8) is higher than the ex post per-unit impact using the same number of units. It is unclear how the ex ante per-unit values were determined. However, the DUOM is most likely *not* the AF of water pumped, since it varies between the kWh and kW.

**Exhibit 4.8**
**Gross Per-Unit Impacts with Ex Ante DUOM**

| End Use | DUOM | N of DUOM | Ex Ante Gross Per-Unit Impacts | | |
|---|---|---|---|---|---|
| | | | kWh | kW | Therms |
| **Ag Pumping and Related** | From E-table | 83,424 for kW and 172,317 for kWh | 103 | 0.019 | |
| **Refrigeration** | Application | 13 | 184,054 | 32.0 | - |
| **Greenhouse Heat Curtain** | Application | 11 | - | - | 52,784 |

| End Use | DUOM | N of DUOM | Ex Post Gross Per-Unit Impacts | | |
|---|---|---|---|---|---|
| | | | kWh | kW | Therms |
| **Ag Pumping and Related** | From E-table | 83,424 for kW and 172,317 for kWh | 34 | 0.017 | |
| **Refrigeration** | Application | 13 | 196,149 | 21.9 | - |
| **Greenhouse Heat Curtain** | Application | 11 | - | - | 34,556 |

| End Use | DUOM | N of DUOM | Per-Unit Realization Rates | | |
|---|---|---|---|---|---|
| | | | kWh | kW | Therms |
| **Ag Pumping and Related** | From E-table | 83,424 for kW and 172,317 for kWh | 0.33 | 0.92 | |
| **Refrigeration** | Application | 13 | 1.07 | 0.69 | - |
| **Greenhouse Heat Curtain** | Application | 11 | - | - | 0.65 |

## *4.7 Net Per-Unit Impacts*

The net per-unit impacts are shown in Exhibit 4.9.

**Exhibit 4.9**
**Net Per-Unit Impacts**

| End Use | Measure Description | DUOM | N of DUOM | | Ex Post Net Per-Unit Impacts | | |
|---|---|---|---|---|---|---|---|
| | | | Electric | Gas | kWh | kW | Therms |
| **Ag Pumping and Related** | Pump Repair | AF of Water Pumped | 95,944 | - | 37 | 0.000 | - |
| | Low-Pressure Nozzles | | 10,321 | - | 7 | 0.003 | - |
| | Micro-Irrigation Conv. | | 4,770 | - | 184 | 0.222 | - |
| | **Ag Pumping and Related End Use Total** | | 111,035 | - | 40 | 0.010 | - |
| **Refrigeration** | High-Capacity Condenser | Tons of Refrigeration (THR) | 3,512 | - | 544 | 0.061 | - |
| | Strip Curtains for Walk-In | | 0 | - | 0 | 0.000 | - |
| | Condensate Evaporator | | 49 | - | 26 | 0.002 | - |
| | **Refrigeration End Use Total** | | 3,561 | - | 537 | 0.060 | - |
| **Greenhouse Heat Curtain Total** | Greenhouse Heat Curtain | Square Foot of Heat Curtain | - | 789,069 | - | - | 0.36 |

Since the net-to-gross ratios are the same for both the ex ante and ex post results, the same explanations apply as presented in section 4.6.

# 5. RECOMMENDATIONS

## *5.1 Evaluation Methods*

The recommendations on the evaluation methods refer to the engineering analysis used for the gross impact analysis, since no net analysis was performed. Our recommendations are:

- The use of the PG&E pump test database to focus on which pump repair sites should be tested was very successful. It effectively targeted resources where they would provide the best information. One-third of the pump repairs were able to have pump-specific impacts. We recommend this practice be continued in any future evaluation of this measure.
- Refrigeration sites that included oversized condensers tended to be large and complex. On-site audits are imperative for this measure in any future evaluation.

## *5.2 Program Design*

The overall recommendations regarding program design are:

- Closely check how the low-pressure sprinkler nozzle rebated sites are using the nozzles within the system for each application. Verification that pressure has been decreased at the pump should be required before granting the rebate.
- Have a list of refrigerators and freezers, by manufacturer and model, that are eligible for rebates under the non-electric condensate Retrofit Express measure. This should expedite rebates and assure that the anticipated savings are achieved.
- Require a minimum thermostat setpoint of 65°F for greenhouses when rebating heat curtains.
- Set the demand impact to zero for pump repairs in all future projected savings.

### 5.2.1 Protocols

The evaluation team makes no recommendations on the Protocols and the requirements set for the evaluation.

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# 6. CADMAC WAIVER

Two requests for retroactive waivers were submitted to CADMAC for the 1997 AEEI programs.

The first AEEI waiver was approved June 17, 1998. This waiver allowed:

- A simplified engineering model supported by telephone and field data collection to estimate the impacts for the refrigeration and greenhouse end uses.
- Use of a net-to-gross ratio of 0.75 for the Ag sector conditioned on conducting a survey-based market effects study of four key pumping end-use market barriers.

The second AEEI waiver was approved January 20, 1999. This waiver allowed:

- Reporting on per-project and relevant per-unit bases for refrigeration and greenhouse heat curtain end uses. For greenhouse heat curtains, the proposed per-unit DUOM was “Load impacts per-square foot of heat curtain installed.” For the refrigeration end use, the proposed per-unit DUOM would be “load impacts per ton of refrigeration affected.”

Next, the waivers are shown in their entirety.

**PACIFIC GAS & ELECTRIC COMPANY**
**REQUEST FOR RETROACTIVE WAIVER FOR**
**1997 AGRICULTURAL SECTOR**
**ENERGY EFFICIENCY INCENTIVES (EEI) PROGRAMS**

Study ID: 335A (Pumping), 335B (Refrigeration), and 335C (Greenhouse Heat Curtain)

Date Approved: June 17, 1998

**Summary of PG&E Request**

This waiver requests deviations from, or clarifications of, the Protocols[3] by PG&E for the 1997 Agricultural Sector Energy Efficiency Incentives (EEI) Evaluation[4]. PG&E seeks approval to: (1) use a Simplified Engineering Model supported by telephone surveys and on-site data collection to estimate the gross impacts for the refrigeration and greenhouse end-uses, and (2) conduct a market effects study in place of a net-to-gross analysis, applying a default net-to-gross ratio to the sector. (Note: items numbers (1) and (2) above referred to in each of the following sections.)

Each of these requests evolve from the evaluation of the 1994 through 1996 PG&E Agricultural programs, the reviews of those program evaluations, the limited size of the participant population, and the limited size of the PG&E agricultural sector in general.

**Proposed Waiver**

PG&E seeks CADMAC approval to: (see Table A for Summary)

**(1) Allow the use of Simplified Engineering Models** (as specified in Appendix A, page A-2 of the Protocols) supported by census telephone survey and on-site data collection to estimate impacts for the refrigeration and greenhouse heat curtain end-uses.

Parameters and Protocol Requirements

Table C-6 is unclear as to the method required to compute gross impacts. Under "Participant Group", item 2 would suggest that a Simplified Engineering Model would be adequate, while item 4 suggests that if billing analysis is not used, "the analysis will rely on direct end-use metering".

Rationale

PG&E's 1997 PG&E agricultural program includes 9 greenhouse heat curtain sites and 13 refrigeration sites representing approximately 11 and 12 percent of the agricultural sector avoided cost, respectively. Metering of these sites would be prohibitively expensive and is unlikely to result in improved estimates of savings. Therefore, PG&E seeks approval to use a participant-based engineering model supported by field data collection for a census of all participants to estimate the impacts for these 22 sites.

A similar waiver was granted for the 1995 (approved October 1996) and 1996 (approved July 22, 1997) for PG&E's Agricultural Sector evaluations.

**(2) Instead of a net-to-gross study, allow the use of a default net-to-gross ratio of 0.75 for the agricultural sector, subject to the condition that PG&E conduct a telephone survey based market effects study of four key market barriers for the pumping and pumping related end-use.** The final report for this study would be submitted to CADMAC by March 30, 1999. (A short study description is attached.)

[3] Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings for Demand-Side Management Programs

[4] The first year earnings claim for the 1997 Agricultural Sector is approximately $1,220,000.

Parameters and Protocol Requirements

Table 5, item B.2. requires the estimate of net impacts. In the Agricultural Sector this has been accomplished by estimating a gross impact and multiplying it by an estimated Net-to-Gross ratio.

Rationale

Allowing PG&E to substitute a forward-looking market effects study for the Protocol required net-to-gross assessment would (1) supply useful information on the program's effectiveness in modifying the market, and (2) further assess the usefulness of this technique for measuring program effects on market barriers. As this is a small program, a market effects study only makes sense for the largest end-use, pumping, since the other end-uses have fewer than 13 participants each.

This is similar to a waiver granted for PG&E's 1996 Agricultural Sector EMS Program evaluation (approved July 22, 1997, modified November 21, 1997).

**Conclusion**

PG&E is seeking retroactive waivers to clearly define, in advance, acceptable methods for performing the 1997 Agricultural impact evaluation of the EEI programs. Recommendations in this waiver are designed to maximize the quality and value of evaluation results. The proposed waiver allowing engineering modeling clarifies the protocol requirements while supporting reasonable estimations of gross program impacts. The waiver allowing a market effects study rather than conducting a net-to-gross analysis seeks to maximize information useful to future programs.

# TABLE A

| IMPACT MEASUREMENT REQUIREMENTS - TABLE C-6 AND TABLE 5 | | | |
|---|---|---|---|
| **Parameters** | **Protocol Requirements** | **Waiver Alternative** | **Rationale** |
| End Use Consumption and Load Impact Model | LIRM or CE (calibrated engineering) or Simplified Engineering Model | Allow Simplified Engineering Model supported by telephone and field data collection to estimate the impacts for the refrigeration and greenhouse end-uses. | Small number of sites makes use of LIRM or regression method impossible. End-use metering is prohibitively expensive for the complex sites and effort is disproportionate to savings. |
| Net Load Impacts | Study-based Net Load Impacts | Use of a NTG ratio of 0.75 for sector conditioned on conducting a survey-based market effects study of four key pumping end-use market barriers. | A market effects study would supply information that is more useful to future agricultural pumping programs and future market effects assessment efforts. |

## *Proposed 1997 Agricultural Sector Market Effects Study*

Pacific Gas & Electric (PG&E) proposes conducting a market effects study of the PG&E's Agricultural Sector pumping end-use. The study will attempt to assess the market for efficient technologies and practices and test or study the market effects of PG&E's 1994-1997 Energy Efficiency Incentives (EEI) Programs. A market characterization will guide the formulation of the research plan and survey instrument. In particular, the effects will be measured in terms of the extent to which the program has been able to reduce the 'barriers' faced by the market for repairs/retrofit of pumps or pumping related equipment. At this stage we anticipated using discrete choice models based on the billing data and information from a survey of EEI participants and a comparison group.

The planned approach will collect data via telephone interviews of a census of participants (~136) and a larger sample of nonparticipants (250). Experience has shown that limiting the survey length to 12 minutes results in high completion rates (~80%) in this sector. Since the population of participants is relatively small, high participant completion rates are required. The goal of the survey is to determine the level of awareness among customers regarding efficient technologies/practices, their beliefs/attitudes regarding the use of energy efficient technologies/practices, and beliefs/attitudes regarding projected future purchasing decisions. In order assess the change in the level of awareness or attitude, information is required for the same customers over a period of time. Participants can be relied on to correctly report current and future perceptions/beliefs. However, since it is not possible to determine a participants true pre-participation attitude, comparison group responses will be used as a proxy for pre-participation beliefs.

In the best of worlds it would be preferable to identify a control area that has not been affected by a utility agricultural incentives program, then survey the control area customers for use as a baseline reference. This is not practical in the current study because (1) under the currently evolving deregulation environment obtaining customer names and telephone numbers would be difficult and time consuming, and (2) the current evaluation/reporting timeline does not allow the time necessary to develop this information, conduct the survey, complete the analysis and report the results.

Along with the customer survey used to reveal the demand side effects, a survey of pump dealers is planned to attempt to assess the supply side effects. The demand side effect and the supply side effect will be compared.

It is anticipated that the data will be analyzed using discrete choice analysis techniques. The possible use use of multinomial logit or probit model forms, and proxy quantitative data or revealed preference data to be used along with the survey, will be reviewed. Criteria will include the applicability of the modeling approach to the study objectives, the availability and cost of appropriate modeling software, and whether the data collection approach and the modeling approach are compatible. Modeling alternatives were reviewed during the 1996 EMS Agricultural Market Effects Study. This review revealed that specialized software for the specific type of modeling planned was either not available or extremely expensive for a one-time application. General statistical software packages (such as SAS) were able to perform such modeling when applied under specific constraints. An appropriate balance will be sought among the primary objectives of (1) developing a causal relationship between the changes in the customers' perception, opinions, and purchase decisions about efficient technologies/practices and the program participation, and (2) contributing to the art of measuring market effects. The final choice of modeling approach will be discussed with the PG&E project manager, along with the reasons for rejection of alternative approaches. A discussion of the model selection process will be included in the project report.

# RETROACTIVE WAIVER FOR 1997 AGRICULTURAL SECTOR ENERGY EFFICIENCY INCENTIVES (EEI) PROGRAMS

Study ID: 335B (Refrigeration), and 335C (Greenhouse Heat Curtain)
Approved by CADMAC on January 20, 1999

This waiver proposes clarifications of the Protocols by PG&E for the 1997 Agricultural Sector Energy Efficiency Incentives (EEI) Evaluation of the refrigeration and greenhouse heat curtain end uses.

## Proposed Waiver

PG&E seeks CADMAC approval to **allow reporting of results in more appropriate DUOMs for the refrigeration and greenhouse heat curtain end-uses.** PG&E wishes to report the results for each of these end uses on a per project basis and on a relevant per unit basis. For greenhouse heat curtains the proposed per unit DUOM would be "Load impacts per square foot of heat curtain installed". For the refrigeration end use the proposed per unit DUOM would be "Load impacts per ton of refrigeration affected". The current DUOM for Protocol Table C-6 are "Load impacts per acre foot of water pumped".

## Rationale

PG&E's 1997 PG&E agricultural program includes 9 greenhouse heat curtain sites and 13 refrigeration sites representing approximately 11 and 12 percent of the agricultural sector avoided cost, respectively. Reporting results for greenhouses and refrigeration projects on a "Load impacts per acre foot of water pumped" would make no sense. PG&E proposes to report them on a per project basis (as is done in the Industrial Process end use in Table C-5) and on a per unit basis. This should maximize the usefulness of the results to users of the reports.

A similar waiver was granted for the Lighting end use in PG&E's 1996 (approved July 22, 1997) Agricultural Sector EEI evaluation.

**IMPACT MEASUREMENT REQUIREMENTS**

**FOR PROTOCOLS TABLE C-6 AND TABLE 5**

| Parameters | Protocol Requirements | Waiver Alternative | Rationale |
|---|---|---|---|
| Designated Unit of Measure | Load impacts per acre foot of water pumped | Allow reporting on a per project basis and on a relevant per unit basis for refrigeration and greenhouse heat curtain end uses. For greenhouse heat curtains the proposed per unit DUOM would be "Load impacts per square foot of heat curtain installed". For the refrigeration end use the proposed per unit DUOM would be "Load impacts per ton of refrigeration affected". | The Pumping DUOM is the only one specified in Table C-6. It does not make sense for other end uses. Reporting the results on both a per project and the proposed per unit basis will make results most useful to future users of the results. |

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# 7. PROTOCOL TABLES 6 AND 7

## *7.1 Protocol Table 6, Pumping End Use*

***Protocol Table 6 (Items 1-5)***
***Results of Impact Measurement Study***
***PG&E 1997 Agricultural Sector***
***Agricultural Pumping and Related End Use***
***Study ID 335A***

| Table Item | | Agricultural Sector | | |
|---|---|---|---|---|
| Item Number Number | Result Description | Estimate | Confidence Interval* 90% | Confidence Interval* 80% |
| 1.A | Pre-installation Average kWh (Participant) | 275,911 | - | - |
| | Pre-installation Average kWh (Comparison) | NA | - | - |
| | Pre-installation Per-Unit kWh (Participant) | 409 | - | - |
| | Pre-installation Per-Unit kWh (Comparison) | NA | - | - |
| 1.B | Average Impact Year kWh (Participant) | 203,342 | - | - |
| | Average Impact Year kWh (Comparison) | NA | - | - |
| | Impact Year kWh/Unit (Participant) | 296 | - | - |
| | Impact Year kWh/Unit (Comparison) | NA | - | - |
| 2.A | Average Gross Peak kW Impact | 9.80 | - | - |
| | Average Gross Annual kWh Impact | 40,095 | - | - |
| | Average Gross Annual Therm Impact | - | - | - |
| | Average Net Peak kW Impact | 7.35 | - | - |
| | Average Net Annual kWh Impact | 30,071 | - | - |
| | Average Net Annual Therm Impact | - | - | - |
| 2.B | Per-Unit Gross Peak kW Impacts | 0.013 | - | - |
| | Per-Unit Gross Annual kWh Impacts | 53 | - | - |
| | Per-Unit Gross Annual Therm Impacts | - | - | - |
| | Per-Unit Net Peak kW Impacts | 0.010 | - | - |
| | Per-Unit Net Annual kWh Impacts | 40 | - | - |
| | Per-Unit Net Annual Therm Impacts | - | - | - |
| 2.C | Percent change in usage of the participant group | -26.3% | - | - |
| | Percent change in usage of the comparison group | NA | - | - |
| 2.D.1 | Gross Demand Realization Rate | 0.44 | - | - |
| | Gross Energy Realization Rate | 0.69 | - | - |
| | Gross Therm Realization Rate | - | - | - |
| | Net Demand Realization Rate | 0.44 | - | - |
| | Net Energy Realization Rate | 0.69 | - | - |
| | Net Therm Realization Rate | - | - | - |
| 2.D.2 | Per-Unit Gross Demand Realization Rate | 0.69 | - | - |
| | Per-Unit Gross Energy Realization Rate | 0.52 | - | - |
| | Per-Unit Gross Annual Therm Realization Rate | - | - | - |
| | Per-Unit Net Demand Realization Rate | 0.69 | - | - |
| | Per-Unit Net Energy Realization Rate | 0.52 | - | - |
| | Per-Unit Net Therm Realization Rate | - | - | - |
| 3.A | NTG Ratio Based on Average kWh Impacts | 0.75 | - | - |
| | NTG Ratio Based on Average kW Impacts | 0.75 | - | - |
| | NTG Ratio Based on Average Therm Impacts | - | - | - |
| 3.B | NTG Ratio Based on Per-Unit Average kWh Impact | 0.75 | - | - |
| | NTG Ratio Based on Per-Unit Average kW Impacts | 0.75 | - | - |
| | NTG Ratio Based on Per-Unit Average Therm Impa | - | - | - |
| 3.C | NTG Ratio Based on Percent change in kWh usage relative to base kWh usage | NA | - | - |
| 4.A | Pre Average AF Water Pumped (Participant) | 2,437 | - | - |
| | Pre Average AF Water Pumped (Comparison) | NA | - | - |
| 4.B | Post Average AF Water Pumped (Participant) | 3,477 | - | - |
| | Post Average AF Water Pumped (Comparison) | NA | - | - |

*No confidence intervals are provided for gross impacts since they were point estimates

***Protocol Table 6 (Item 6)***
***Results of Impact Measurement Study***
***PG&E 1997 Agricultural Sector***
***Agricultural Pumping and Related End Use***
***Study ID 335A***

| Measure | Designated Unit of Measure (DUOM) | Participant Group | Program Population |
|---|---|---|---|
| Pump Repair | AF Water Pumped | 95,944 | 95,944 |
| Low-Pressure Sprinkler Nozzle | AF Water Pumped | 10,321 | 10,321 |
| Micro-drip Conversion | AF Water Pumped | 4,770 | 4,770 |
| **Total** | | 111,035 | 111,035 |

## 7.2 Protocol Table 6, Refrigeration End Use

***Protocol Table 6 (Items 1-5)***
***Results of Impact Measurement Study***
***PG&E 1997 Agricultural Sector***
***Refrigeration End Use***
***Study ID 335B***

| Table Item | | Agricultural Sector | | | |
|---|---|---|---|---|---|
| Item Number | Result Description | Estimate DUOM=THR | Estimate DUOM=Site | Confidence Interval* 90% | Confidence Interval* 80% |
| 1.A | Pre-installation Average kWh (Participant) | 2,478,058 | 2,478,058 | - | - |
| | Pre-installation Average kWh (Comparison) | NA | NA | - | - |
| | Pre-installation Per-Unit kWh (Participant) | 9,047 | 2,478,058 | - | - |
| | Pre-installation Per-Unit kWh (Comparison) | NA | NA | - | - |
| 1.B | Average Impact Year kWh (Participant) | 2,739,486 | 2,739,486 | - | - |
| | Average Impact Year kWh (Comparison) | NA | NA | - | - |
| | Impact Year kWh/Unit (Participant) | 10,001 | 2,739,486 | - | - |
| | Impact Year kWh/Unit (Comparison) | NA | NA | - | - |
| 2.A | Average Gross Peak kW Impact | 21.94 | 21.94 | - | - |
| | Average Gross Annual kWh Impact | 196,149 | 196,149 | - | - |
| | Average Gross Annual Therm Impact | - | - | - | - |
| | Average Net Peak kW Impact | 16.46 | 16.46 | - | - |
| | Average Net Annual kWh Impact | 147,112 | 147,112 | - | - |
| | Average Net Annual Therm Impact | - | - | - | - |
| 2.B | Per-Unit Gross Peak kW Impacts | 0.080 | 21.94 | - | - |
| | Per-Unit Gross Annual kWh Impacts | 716 | 196,149 | - | - |
| | Per-Unit Gross Annual Therm Impacts | - | - | - | - |
| | Per-Unit Net Peak kW Impacts | 0.060 | 16.46 | - | - |
| | Per-Unit Net Annual kWh Impacts | 537 | 147,112 | - | - |
| | Per-Unit Net Annual Therm Impacts | - | - | - | - |
| 2.C | Percent change in usage of the participant group | 10.5% | 10.5% | - | - |
| | Percent change in usage of the comparison group | NA | NA | - | - |
| 2.D.1 | Gross Demand Realization Rate | 0.69 | 0.69 | - | - |
| | Gross Energy Realization Rate | 1.07 | 1.07 | - | - |
| | Gross Therm Realization Rate | - | - | - | - |
| | Net Demand Realization Rate | 0.69 | 0.69 | - | - |
| | Net Energy Realization Rate | 1.07 | 1.07 | - | - |
| | Net Therm Realization Rate | - | - | - | - |
| 2.D.2 | Per-Unit Gross Demand Realization Rate | 0.003 | 0.69 | - | - |
| | Per-Unit Gross Energy Realization Rate | 0.004 | 1.07 | - | - |
| | Per-Unit Gross Annual Therm Realization Rate | - | - | - | - |
| | Per-Unit Net Demand Realization Rate | 0.003 | 0.69 | - | - |
| | Per-Unit Net Energy Realization Rate | 0.004 | 1.07 | - | - |
| | Per-Unit Net Therm Realization Rate | - | - | - | - |
| 3.A | NTG Ratio Based on Average kWh Impacts | 0.75 | 0.75 | - | - |
| | NTG Ratio Based on Average kW Impacts | 0.75 | 0.75 | - | - |
| | NTG Ratio Based on Average Therm Impacts | - | - | - | - |
| 3.B | NTG Ratio Based on Per-Unit Average kWh Impact | 0.75 | 0.75 | - | - |
| | NTG Ratio Based on Per-Unit Average kW Impacts | 0.75 | 0.75 | - | - |
| | NTG Ratio Based on Per-Unit Average Therm Impa | - | - | - | - |
| 3.C | NTG Ratio Based on Percent change in kWh usage relative to base kWh usage | NA | NA | - | - |
| 4.A | Pre Average kWh (Participant) | 32,214,750 | | - | - |
| | Pre Average kWh (Comparison) | NA | | - | - |
| 4.B | Post Average kWh (Participant) | 35,613,320 | | - | - |
| | Post Average kWh (Comparison) | NA | | - | - |

*No confidence intervals are provided for gross impacts since they were point estimates

***Protocol Table 6 (Item 6)***
***Results of Impact Measurement Study***
***PG&E 1997 Agricultural Sector***
***Refrigeration End Use***
***Study ID 335B***

| Measure | Designated Unit of Measure (DUOM) | Participant Group | Program Population |
|---|---|---|---|
| High-Capacity Condenser | Tons of Refrigeration (THR) | 3,512 | 3,512 |
| Strip Curtains for Walk-In* | Tons of Refrigeration (THR) | - | - |
| Non-electric Condensate Evaporator | Tons of Refrigeration (THR) | 49 | 49 |
| **Total** | | 3,561 | 3,561 |
| High-Capacity Condenser | Site | 10 | 10 |
| Strip Curtains for Walk-In | Site | 1 | 1 |
| Non-electric Condensate Evaporator | Site | 2 | 2 |
| **Total** | | 13 | 13 |

*Unable to determine the THR for this one site - impact was zero for site so disregarded

# 7.3 Protocol Table 6, Greenhouse Heat Curtain End Use

***Protocol Table 6 (Items 1-5)***
***Results of Impact Measurement Study***
***PG&E 1997 Agricultural Sector***
***Greenhouse Heat Curtain End Use***
***Study ID 335C***

| Table Item | | Agricultural Sector | | | |
|---|---|---|---|---|---|
| Item Number Number | Result Description | Estimate DUOM=Sq Ft | Estimate DUOM=Site | Confidence Interval* 90% | 80% |
| 1.A | Pre-installation Average Therm (Participant) | 327,574 | 327,574 | - | - |
| | Pre-installation Average Therm (Comparison) | NA | NA | - | - |
| | Pre-installation Per-Unit Therm (Participant) | 5 | 327,574 | - | - |
| | Pre-installation Per-Unit Therm (Comparison) | NA | NA | - | - |
| 1.B | Average Impact Year Therm (Participant) | 190,903 | 190,903 | - | - |
| | Average Impact Year Therm (Comparison) | NA | NA | - | - |
| | Impact Year Therm/Unit (Participant) | 2.66 | 190,903 | - | - |
| | Impact Year Therm/Unit (Comparison) | NA | NA | - | - |
| 2.A | Average Gross Peak kW Impact | - | - | - | - |
| | Average Gross Annual kWh Impact | - | - | - | - |
| | Average Gross Annual Therm Impact | 34,556 | 34,556 | - | - |
| | Average Net Peak kW Impact | - | - | - | - |
| | Average Net Annual kWh Impact | - | - | - | - |
| | Average Net Annual Therm Impact | 25,917 | 25,917 | - | - |
| 2.B | Per-Unit Gross Peak kW Impacts | - | - | - | - |
| | Per-Unit Gross Annual kWh Impacts | - | - | - | - |
| | Per-Unit Gross Annual Therm Impacts | 0.48 | 34,556 | - | - |
| | Per-Unit Net Peak kW Impacts | - | - | - | - |
| | Per-Unit Net Annual kWh Impacts | - | - | - | - |
| | Per-Unit Net Annual Therm Impacts | 0.36 | 25,917 | - | - |
| 2.C | Percent change in usage of the participant group | -41.7% | -41.7% | - | - |
| | Percent change in usage of the comparison group | NA | NA | - | - |
| 2.D.1 | Gross Demand Realization Rate | - | - | - | - |
| | Gross Energy Realization Rate | - | - | - | - |
| | Gross Therm Realization Rate | 0.65 | 0.65 | - | - |
| | Net Demand Realization Rate | - | - | - | - |
| | Net Energy Realization Rate | - | - | - | - |
| | Net Therm Realization Rate | 0.65 | 0.65 | - | - |
| 2.D.2 | Per-Unit Gross Demand Realization Rate | - | - | - | - |
| | Per-Unit Gross Energy Realization Rate | - | - | - | - |
| | Per-Unit Gross Annual Therm Realization Rate | 0.00 | 0.65 | - | - |
| | Per-Unit Net Demand Realization Rate | - | - | - | - |
| | Per-Unit Net Energy Realization Rate | - | - | - | - |
| | Per-Unit Net Therm Realization Rate | 0.00 | 0.65 | - | - |
| 3.A | NTG Ratio Based on Average kWh Impacts | - | - | - | - |
| | NTG Ratio Based on Average kW Impacts | - | - | - | - |
| | NTG Ratio Based on Average Therm Impacts | 0.75 | 0.75 | - | - |
| 3.B | NTG Ratio Based on Per-Unit Average kWh Impact | - | - | - | - |
| | NTG Ratio Based on Per-Unit Average kW Impacts | - | - | - | - |
| | NTG Ratio Based on Per-Unit Average Therm Impa | 0.75 | 0.75 | - | - |
| 3.C | NTG Ratio Based on Percent change in kWh usage relative to base kWh usage | NA | NA | - | - |
| 4.A | Pre Average Therm (Participant) | 3,603,316 | | - | - |
| | Pre Average Therm (Comparison) | NA | | - | - |
| 4.B | Post Average Therm (Participant) | 2,099,930 | | - | - |
| | Post Average Therm (Comparison) | NA | | - | - |

*No confidence intervals are provided for gross impacts since they were point estimates

***Protocol Table 6 (Item 6)***
***Results of Impact Measurement Study***
***PG&E 1997 Agricultural Sector***
***Greenhouse Heat Curtain End Use***
***Study ID 335C***

| **Measure** | **Designated Unit of Measure (DUOM)** | **Participant Group** | **Program Population** |
|---|---|---|---|
| Greenhouse Heat Curtain | Square Foot of Heat Curtain | 789,069 | 789,069 |
| **Total** | | 789,069 | 789,069 |
| Greenhouse Heat Curtain | Site | 11 | 11 |
| **Total** | | 11 | 11 |

## *7.4 Protocol Table 7 – Pumping and Related End Use (Study #335A)*

**1997 Agricultural EEI Program**
**Evaluation of Pumping and Related End Use**
**PG&E Study ID # 335A**

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). 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.

### 7.4.1 Overview Information

*7.4.1.1 Study Title and Study ID Number*

| | |
|---|---|
| Study Title: | Evaluation of PG&E's 1997 Agricultural Energy Efficiency Incentives (AEEI)<br>Program for Agricultural Sector Pumping and Related End Use Technologies. |
| Study ID Number: | 335A |

*7.4.1.2 Program, Program Year and Program Description*

| | |
|---|---|
| Program: | PG&E Agricultural EEI Program, Agricultural Sector Pumping and Related End Use Technologies. |
| Program Year: | Rebates Received in the 1997 Calendar Year. |
| Program Description: | Refer to section 2.1 for a detailed description of the program. |

*7.4.1.3 End Uses and/or Measures Covered*

| | |
|---|---|
| End Use Covered: | Agricultural Pumping Technologies |
| Measures Covered: | Pump Repair<br>Low-Pressure Sprinkler Nozzles<br>Sprinkler to Micro Irrigation Conversion |

*7.4.1.4 Methods and Models Use*

The PG&E AEEI Program evaluation consisted of an engineering analysis of gross energy and demand impacts. A retroactive waiver had been accepted by CADMAC to allow the evaluation team to replace the net analysis with a market effects study. A default net-to-gross ratio of 0.75 was used in place of the net analysis.

*Gross Impact* - The gross estimates of impact for the pumping and related end use were based upon engineering models using on-site data and a review of ex ante algorithms and assumptions.

*Net effect* – The default net-to-gross ratio of 0.75 was used.

*7.4.1.5 Participant and Comparison Group Definition*

Participant - Participants are defined as those PG&E agricultural customers who received PG&E rebates in the 1997 calendar year for installing at least one pumping measure under the AEEI Program.

Comparison Group – Nonparticipant pre- and post-retrofit pump test data were used to support the analysis.

*7.4.1.6 Analysis Sample Size*

Gross impact – a census was attempted for the participants.

**Exhibit 7.1**
**Sample Summary – Pumping and Related End Use**

| End Use | Population* | Sample Frame | | Final Analysis Sample | |
|---|---|---|---|---|---|
| | | On-Site | Metering | On-Site | Metering |
| Pumping and Related | 148 | 148 | 96 | 138 | 82 |
| Refrigeration | 13 | 13 | 0 | 13 | 0 |
| Greenhouse Heat Curtain | 11 | 11 | 0 | 11 | 0 |
| Total Participant | 172 | 172 | 96 | 162 | 82 |
| 1995 Retention | 126 | 126 | - | 123 | - |

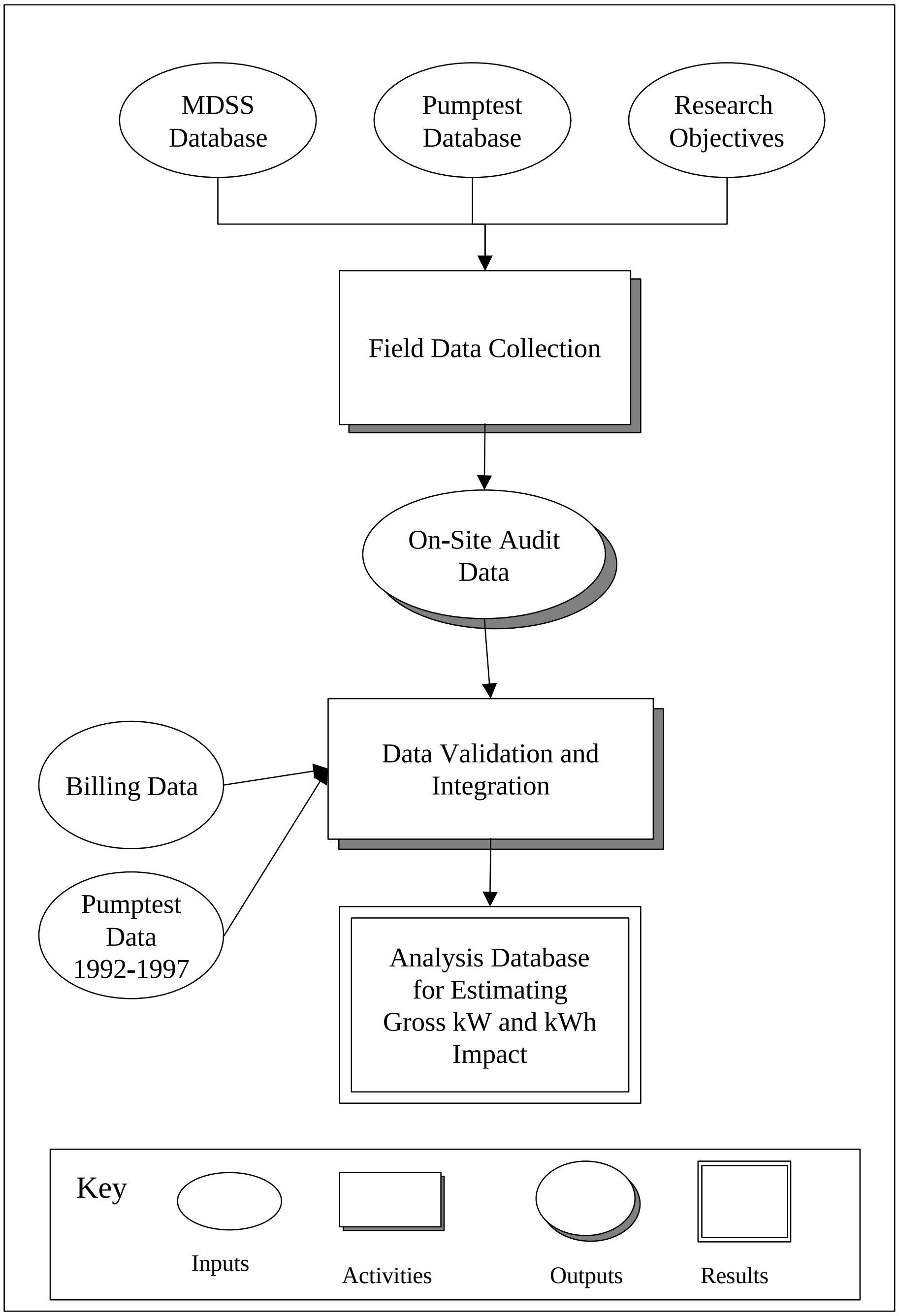
*Participant sample was a census, population refers to application numbers

### 7.4.2 Database Management

*7.4.2.1 Data Description and Flow Chart*

On-site survey data were collected for a census of participants. Sample design was not required since a census is included in the analysis. After the on-site survey of participants, the analysis database was created using the program data, billing data and on-site survey data. Exhibit 7.2 illustrates how each key data element was used to create the final analysis database for the evaluation.

**Exhibit 7.2**
**Final Analysis Database Creation – Pumping and Related End Use**




### *7.4.2.2 Specific Data Sources*

The key analysis data elements and their sources are listed below:

MDSS Tracking Database. - This database, maintained by PG&E, contains program application, rebate, and technical information about installed measures, including measure descriptions, quantities, rebate amounts, and ex ante demand, energy, and therm saving estimates.

PG&E Billing Data - The PG&E billing dataset used for the analysis was pro-rated monthly usage data, calculated by PG&E for each calendar month, and obtained from PG&E's Load Data Services.

PG&E Pump Test Database – This database, maintained by PG&E, contains data from pump tests performed throughout the service territory.

On-Site Audit Data - On-site audit data were collected as part of this evaluation for the participant group. The on-site audit was designed to support the engineering analysis by providing key inputs such as acreage and pump operating plant efficiency.

Other data elements include PG&E program marketing data, program procedural manuals and other industry standard data sources.

#### *7.4.2.3 Data Attrition Process*

All data elements mentioned above were first validated and then merged together to form the final analysis dataset. All data points collected during the on-site audits were kept.

#### *7.4.2.4 Internal Data Quality Procedures*

The evaluation contractor of this project, Equipoise Consulting along with subcontractors, have performed extensive data quality control on all categories of program data, including utility billing data, program tracking data, and on-site data. The data quality procedures are consistent with PG&E's internal guidelines and the guidelines established in the Protocols.

Throughout the course of survey data collection and data analysis, data quality assurance procedures were in place to insure that all usage data used in analysis and all on-site survey data collected was of high quality.

*On-site Survey Data Validation*. – The on-site audits were validated by an agricultural engineer prior to data entry.

#### *7.4.2.5 Unused Data Elements*

All data collected specifically for the Evaluation were utilized in the analysis.

### 7.4.3 Sampling

#### *7.4.3.1 Sampling Procedures and Protocols*

The limited participant population necessitated an attempted census of participants who were expected to contribute data to the engineering analysis. The number of completed participant surveys as mentioned above in section 1.f., reflects such an attempted census.

#### *7.4.3.2 Survey Information*

On-site audit instruments are presented in Appendix B.

#### *7.4.3.3 Statistical Descriptions*

There were no statistical models used in this analysis.

### 7.4.4 Data Screening and Analysis

A detailed discussion of the approach used to estimate the engineering impact for the pumping and related measures is described in Appendix A.

#### *7.4.4.1 Outliers and Missing Data*

When data was unavailable or was as outlier, an average from the rest of the measure was used.

#### *7.4.4.2 Background Variables*

There were no background variables modeled.

#### *7.4.4.3 Data Screening Process*

No data was screened from the engineering analysis.

#### *7.4.4.4 Regression Statistics*

There were no regression models used in this evaluation.

#### *7.4.4.5 Model Specification*

There were no statistical models used in this evaluation.

#### *7.4.4.6 Measurement Errors*

The main source of measurement errors is the on-site 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 miscoded study variables. In this project, we have implemented controls to reduce the systematic bias in the data. These steps include (1) thorough auditor training, and (2) instrument pre-test.

The random measurement error, such as data entry error, has no impact on estimating mean values because the errors are typically unbiased.

#### *7.4.4.7 Autocorrelation*

This is not applicable to an engineering analysis.

#### *7.4.4.8 Heteroskedasticity*

This is not applicable to an engineering analysis.

*7.4.4.9 Collinearity*

This is not applicable to an engineering analysis.

*7.4.4.10 Influential Data Points*

This is not applicable to an engineering analysis.

*7.4.4.11 Missing Data*

When data was unavailable, an average from the rest of the measure was used.

*7.4.4.12 Precision*

Since the engineering estimate of gross kWh savings is a point estimate for any customer, and is calculated for all participants for whom on-site data were available, there is no sampling error associated with it and systematic measurement error is avoided by proactive actions. Thus, the engineering estimate is considered 100% precise.

*7.4.4.13 Engineering Analysis*

The Protocols allow a simplified engineering model to be used for the pumping and related end use. The analysis performed for this evaluation used pump test data from either the PG&E pump test database or site specific tests as inputs into the engineering models. All the savings were seen at one or more pumps with no other loads interacting.

*7.4.4.14 Comparison Group Not Used for Net Analysis*

A waiver allowed the evaluation team to use a default net-to-gross ratio of 0.75.

### 7.4.5 Data Interpretation and Application

A waiver allowed the evaluation team to use a default net-to-gross ratio of 0.75. This value was applied to all gross impact estimates at the measure level.

## *7.5 Protocol Table 7 – Refrigeration End Use (Study #335B)*

**1997 Agricultural EEI Program**
**Evaluation of Refrigeration End Use**
**PG&E Study ID # 335B**

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). 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.

### 7.5.1 Overview Information

#### *7.5.1.1 Study Title and Study ID Number*

| | |
|---|---|
| Study Title: | Evaluation of PG&E's 1997 Agricultural Energy Efficiency Incentives (AEEI)<br>Program for Agricultural Sector Refrigeration End Use Technologies. |
| Study ID Number: | 335B |

#### *7.5.1.2 Program, Program Year and Program Description*

| | |
|---|---|
| Program: | PG&E Agricultural EEI Program, Agricultural Sector Refrigeration End Use Technologies. |
| Program Year: | Rebates Received in the 1997 Calendar Year. |
| Program Description: | Refer to section 2.1 for a detailed description of the program. |

#### *7.5.1.3 End Uses and/or Measures Covered*

| | |
|---|---|
| End Use Covered: | Refrigeration Technologies Used in the Agricultural Sector |
| Measures Covered: | Oversized Condenser<br>Strip Curtain<br>Non-electric Condensate Refrigerator/Freezer |

#### *7.5.1.4 Methods and Models Use*

The PG&E AEEI Program evaluation consisted of an engineering analysis of gross energy and demand impacts. A retroactive waiver had been accepted by CADMAC to allow the evaluation team to replace the net analysis with a market effects study. A default net-to-gross ratio of 0.75 was used in place of the net analysis.

*Gross Impact* - The gross estimates of impact for the refrigeration end use were based upon engineering models using on-site data and a review of ex ante algorithms and assumptions.

*Net effect* – The default net-to-gross ratio of 0.75 was used.

#### *7.5.1.5 Participant and Comparison Group Definition*

Participant - Participants are defined as those PG&E agricultural customers who received PG&E rebates in the 1997 calendar year for installing at least one refrigeration measure under the AEEI Program.

Comparison Group – There was no comparison group used in the engineering analysis. This was allowed by the waiver shown in Section 6.

#### *7.5.1.6 Analysis Sample Size*

Gross impact – a census was attempted for the participants.

**Exhibit 7.3**
**Sample Summary – Refrigeration End Use**

| End Use | Population* | Sample Frame | | Final Analysis Sample | |
|---|---|---|---|---|---|
| | | On-Site | Metering | On-Site | Metering |
| Pumping and Related | 148 | 148 | 96 | 138 | 82 |
| Refrigeration | 13 | 13 | 0 | 13 | 0 |
| Greenhouse Heat Curtain | 11 | 11 | 0 | 11 | 0 |
| Total Participant | 172 | 172 | 96 | 162 | 82 |
| 1995 Retention | 126 | 126 | - | 123 | - |

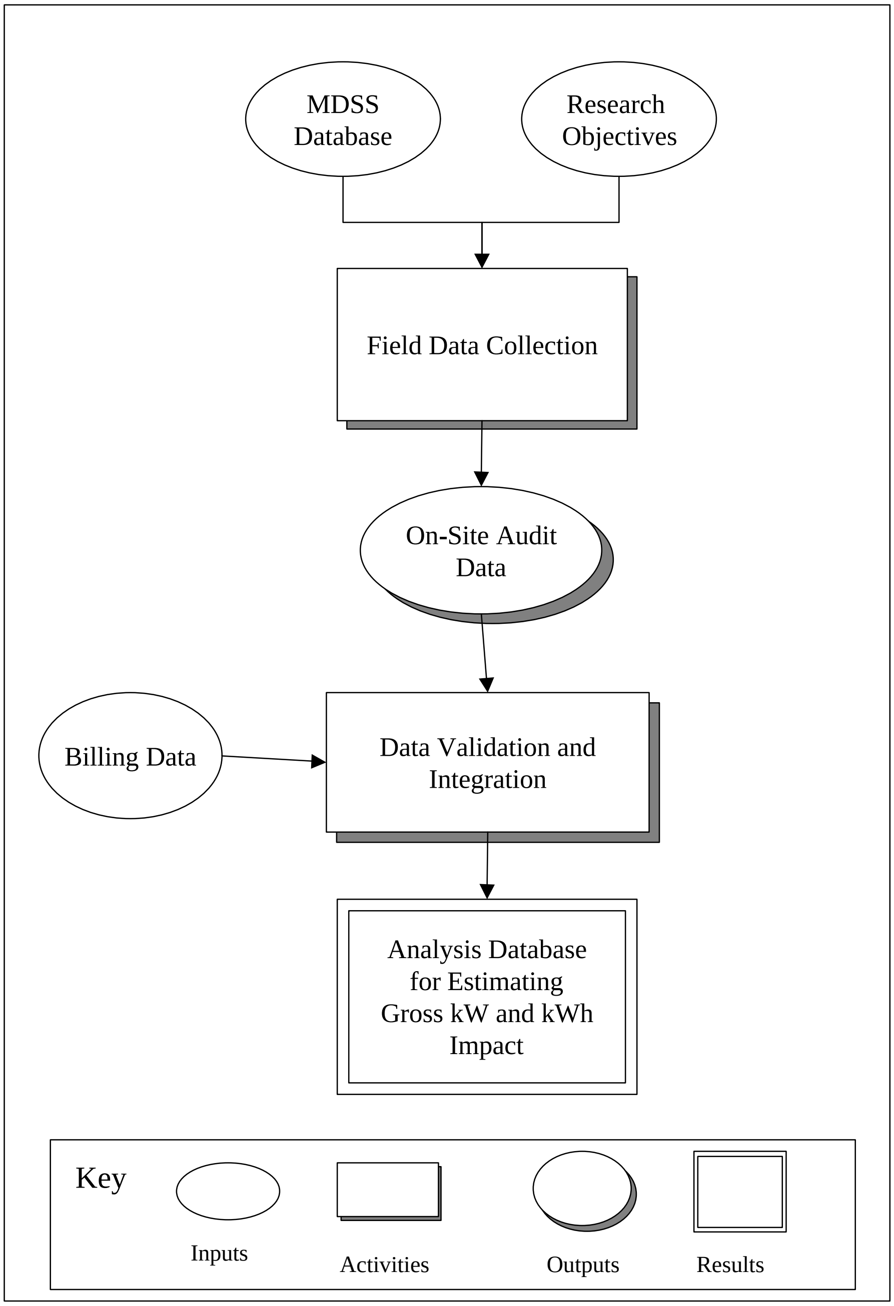
*Participant sample was a census, population refers to application numbers

### 7.5.2 Database Management

#### *7.5.2.1 Data Description and Flow Chart*

On-site survey data were collected for a census of participants. Sample design was not required since a census is included in the analysis. After the on-site survey of participants, the analysis database was created using the program data, billing data and on-site survey data. Exhibit 7.2 illustrates how each key data element was used to create the final analysis database for the evaluation.

**Exhibit 7.4**
**Final Analysis Database Creation – Refrigeration End Use**




*7.5.2.2 Specific Data Sources*

The key analysis data elements and their sources are listed below:

MDSS Tracking Database. - This database, maintained by PG&E, contains program application, rebate, and technical information about installed measures, including measure descriptions, quantities, rebate amounts, and ex ante demand, energy, and therm saving estimates.

PG&E Billing Data - The PG&E billing dataset used for the analysis was pro-rated monthly usage data, calculated by PG&E for each calendar month, and obtained from PG&E's Load Data Services.

On-Site Audit Data - On-site audit data were collected as part of this evaluation for the participant group. The on-site audit was designed to support the engineering analysis by providing key inputs such as compressor horsepower and refrigeration capacity.

Other data elements include PG&E program marketing data, program procedural manuals and other industry standard data sources.

#### *7.5.2.3 Data Attrition Process*

All data elements mentioned above were first validated and then merged together to form the final analysis dataset. All data points collected during the on-site audits were kept.

#### *7.5.2.4 Internal Data Quality Procedures*

The evaluation contractor of this project, Equipoise Consulting along with subcontractors, have performed extensive data quality control on all categories of program data, including utility billing data, program tracking data, and on-site data. The data quality procedures are consistent with PG&E's internal guidelines and the guidelines established in the Protocols.

Throughout the course of survey data collection and data analysis, data quality assurance procedures were in place to insure that all usage data used in analysis and all on-site survey data collected was of high quality.

#### *7.5.2.5 Unused Data Elements*

All data collected specifically for the Evaluation were utilized in the analysis.

### 7.5.3 Sampling

#### *7.5.3.1 Sampling Procedures and Protocols*

The limited participant population necessitated an attempted census of participants who were expected to contribute data to the engineering analysis. The number of completed participant surveys as mentioned above in section 1.f., reflects a census.

#### *7.5.3.2 Survey Information*

On-site audit instruments are presented in Appendix B.

#### *7.5.3.3 Statistical Descriptions*

There were no statistical models used in this analysis.

### 7.5.4 Data Screening and Analysis

A detailed discussion of the approach used to estimate the engineering impact for the refrigeration measures is described in Appendix A.

#### *7.5.4.1 Outliers and Missing Data*

When data was unavailable or was as outlier, all other data from the site and engineering judgement was used to determine the best data point.

#### *7.5.4.2 Background Variables*

There were no background variables modeled.

#### *7.5.4.3 Data Screening Process*

No data was screened from the engineering analysis.

#### *7.5.4.4 Regression Statistics*

There were no regression models used in this evaluation.

#### *7.5.4.5 Model Specification*

There were no statistical models used in this evaluation.

#### *7.5.4.6 Measurement Errors*

The main source of measurement errors is the on-site 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 miscoded study variables. In this project, we have implemented controls to reduce the systematic bias in the data. These steps included an instrument pre-test.

The random measurement error, such as data entry error, has no impact on estimating mean values because the errors are typically unbiased.

#### *7.5.4.7 Autocorrelation*

This is not applicable to an engineering analysis.

#### *7.5.4.8 Heteroskedasticity*

This is not applicable to an engineering analysis.

#### *7.5.4.9 Collinearity*

This is not applicable to an engineering analysis.

#### *7.5.4.10 Influential Data Points*

This is not applicable to an engineering analysis.

#### *7.5.4.11 Missing Data*

When data was unavailable, an estimate based on all other available data for the site and engineering judgement was used.

#### *7.5.4.12 Precision*

Since the engineering estimate of gross kWh savings is a point estimate for any customer, and is calculated for all participants for whom on-site data were available, there is no sampling error associated with it and systematic measurement error is avoided by proactive actions. Thus, the engineering estimate is considered 100% precise.

#### *7.5.4.13 Engineering Analysis*

The waiver allowed a simplified engineering model to be used for the refrigeration end use. The savings seen by the measures were not interactive with any other loads.

#### *7.5.4.14 Comparison Group Not Used for Net Analysis*

A waiver allowed the evaluation team to use a default net-to-gross ratio of 0.75.

### 7.5.5 Data Interpretation and Application

A waiver allowed the evaluation team to use a default net-to-gross ratio of 0.75. This value was applied to all gross impact estimates at the measure level.

## *7.6 Protocol Table 7 – Greenhouse Heat Curtain End Use (Study #335C)*

**1997 Agricultural EEI Program**
**Evaluation of Greenhouse Heat Curtain End Use**
**PG&E Study ID # 335C**

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). 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.

### 7.6.1 Overview Information

*7.6.1.1 Study Title and Study ID Number*

Study Title: Evaluation of PG&E's 1997 Agricultural Energy Efficiency Incentives (AEEI)
Program for Agricultural Sector Greenhouse Heat Curtain End Use.

Study ID Number: 335C

*7.6.1.2 Program, Program Year and Program Description*

Program: PG&E Agricultural EEI Program, Agricultural Sector Greenhouse Heat Curtain End Use.

Program Year: Rebates Received in the 1997 Calendar Year.

Program Description: Refer to section 2.1 for a detailed description of the program.

*7.6.1.3 End Uses and/or Measures Covered*

End Use Covered: Heat Curtains Used in the Agricultural Sector

Measures Covered: Heat Curtains

*7.6.1.4 Methods and Models Use*

The PG&E AEEI Program evaluation consisted of an engineering analysis of gross energy impacts. A retroactive waiver had been accepted by CADMAC to allow the evaluation team to replace the net analysis with a market effects study. A default net-to-gross ratio of 0.75 was used in place of the net analysis.

*Gross Impact* - The gross estimates of impact for the heat curtain end use were based upon engineering models using on-site data and a review of ex ante algorithms and assumptions.

*Net effect* – The default net-to-gross ratio of 0.75 was used.

#### *7.6.1.5 Participant and Comparison Group Definition*

Participant - Participants are defined as those PG&E agricultural customers who received PG&E rebates in the 1997 calendar year for installing at least one heat curtain measure under the AEEI Program.

Comparison Group – There was no comparison group used in the engineering analysis. This was allowed by the waiver shown in Section 6.

#### *7.6.1.6 Analysis Sample Size*

Gross impact – a census was attempted for the participants.

**Exhibit 7.5**
**Sample Summary – Greenhouse Heat Curtain End Use**

| | | Sample Frame | | Final Analysis Sample | |
|---|---|---|---|---|---|
| **End Use** | **Population*** | **On-Site** | **Metering** | **On-Site** | **Metering** |
| Pumping and Related | 148 | 148 | 96 | 138 | 82 |
| Refrigeration | 13 | 13 | 0 | 13 | 0 |
| Greenhouse Heat Curtain | 11 | 11 | 0 | 11 | 0 |
| Total Participant | 172 | 172 | 96 | 162 | 82 |
| 1995 Retention | 126 | 126 | - | 123 | - |

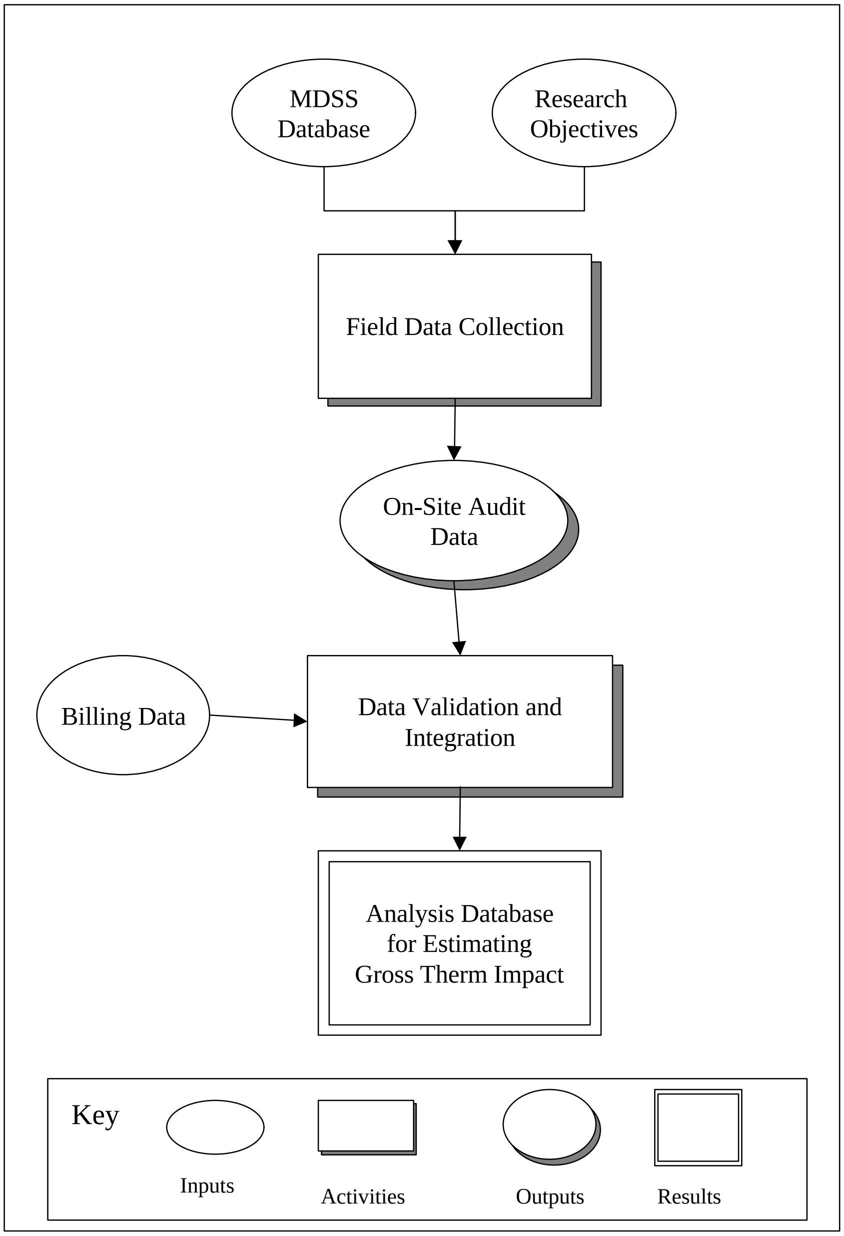
*Participant sample was a census, population refers to application numbers

### 7.6.2 Database Management

#### *7.6.2.1 Data Description and Flow Chart*

On-site survey data were collected for a census of participants. Sample design was not required since a census is included in the analysis. After the on-site survey of participants, the analysis database was created using the program data, billing data and on-site survey data. Exhibit 7.2 illustrates how each key data element was used to create the final analysis database for the evaluation.

**Exhibit 7.6**
**Final Analysis Database Creation – Greenhouse Heat Curtain End Use**




*7.6.2.2 Specific Data Sources*

The key analysis data elements and their sources are listed below:

MDSS Tracking Database. - This database, maintained by PG&E, contains program application, rebate, and technical information about installed measures, including measure descriptions, quantities, rebate amounts, and ex ante demand, energy, and therm saving estimates.

PG&E Billing Data - The PG&E billing dataset used for the analysis was pro-rated monthly usage data, calculated by PG&E for each calendar month, and obtained from PG&E's Load Data Services.

On-Site Audit Data - On-site audit data were collected as part of this evaluation for the participant group. The on-site audit was designed to support the engineering analysis by providing key inputs such as number of peaks and square footage.

Other data elements include PG&E program marketing data, program procedural manuals and other industry standard data sources.

#### *7.6.2.3 Data Attrition Process*

All data elements mentioned above were first validated and then merged together to form the final analysis dataset. All data points collected during the on-site audits were kept.

#### *7.6.2.4 Internal Data Quality Procedures*

The evaluation contractor of this project, Equipoise Consulting along with subcontractors, have performed extensive data quality control on all categories of program data, including utility billing data, program tracking data, and on-site data. The data quality procedures are consistent with PG&E's internal guidelines and the guidelines established in the Protocols.

Throughout the course of survey data collection and data analysis, data quality assurance procedures were in place to insure that all usage data used in analysis and all on-site survey data collected was of high quality.

#### *7.6.2.5 Unused Data Elements*

All data collected specifically for the Evaluation were utilized in the analysis.

### 7.6.3 Sampling

#### *7.6.3.1 Sampling Procedures and Protocols*

The limited participant population necessitated an attempted census of participants who were expected to contribute data to the engineering analysis. The number of completed participant surveys as mentioned above in section 1.f., reflects a census.

#### *7.6.3.2 Survey Information*

On-site audit instruments are presented in Appendix B.

#### *7.6.3.3 Statistical Descriptions*

There were no statistical models used in this analysis.

### 7.6.4 Data Screening and Analysis

A detailed discussion of the approach used to estimate the engineering impact for the heat curtain measure is described in Appendix A.

#### *7.6.4.1 Outliers and Missing Data*

When data was unavailable or was as outlier, all other data from the site and engineering judgement was used to determine the best data point.

#### *7.6.4.2 Background Variables*

There were no background variables modeled.

#### *7.6.4.3 Data Screening Process*

No data was screened from the engineering analysis.

#### *7.6.4.4 Regression Statistics*

There were no regression models used in this evaluation.

#### *7.6.4.5 Model Specification*

There were no statistical models used in this evaluation.

#### *7.6.4.6 Measurement Errors*

The main source of measurement errors is the on-site 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 miscoded study variables. In this project, we have implemented controls to reduce the systematic bias in the data. These steps included an instrument pre-test.

The random measurement error, such as data entry error, has no impact on estimating mean values because the errors are typically unbiased.

#### *7.6.4.7 Autocorrelation*

This is not applicable to an engineering analysis.

#### *7.6.4.8 Heteroskedasticity*

This is not applicable to an engineering analysis.

#### *7.6.4.9 Collinearity*

This is not applicable to an engineering analysis.

##### *7.6.4.10 Influential Data Points*

This is not applicable to an engineering analysis.

##### *7.6.4.11 Missing Data*

When data was unavailable, an estimate based on all other available data for the site and engineering judgement was used.

##### *7.6.4.12 Precision*

Since the engineering estimate of gross kWh savings is a point estimate for any customer, and is calculated for all participants for whom on-site data were available, there is no sampling error associated with it and systematic measurement error is avoided by proactive actions. Thus, the engineering estimate is considered 100% precise.

##### *7.6.4.13 Engineering Analysis*

The waiver allowed a simplified engineering model to be used for the heat curtain end use. The savings seen by the measure were not interactive with any other loads.

##### *7.6.4.14 Comparison Group Not Used for Net Analysis*

A waiver allowed the evaluation team to use a default net-to-gross ratio of 0.75.

### 7.6.5 Data Interpretation and Application

A waiver allowed the evaluation team to use a default net-to-gross ratio of 0.75. This value was applied to all gross impact estimates at the measure level.

This concludes the report on the evaluation of the 1997 Agricultural Sector Programs.

# Appendix A
# Engineering Detailed Computation Methods

# Table of Contents

# Table of Exhibits

# 1. Overview

The 1997 agricultural programs evaluation analyzed three end uses – Ag Pumping and Related Measures, Refrigeration, and Ag Other (Greenhouse Heat Curtains). These three end uses represent 90% of the ex ante avoided costs for the 1997 Agricultural Energy Efficiency Incentive Program (AEEI). A census of the applications had on-site audits performed to gather information for the engineering analyses, as shown in Exhibit 1.1.

**Exhibit 1.1**
**On-Site Audits Performed**

| End Use | PG&E Code * | Measure Description | Number of Applications | Applications Audited |
|---|---|---|---|---|
| **Ag Pumping and Related** | A1 | Pump Repair | 111 | 102 |
| | A40 / A41 / A42 / A43 | Low-Pressure Nozzles | 5 | 4 |
| | A44 / A45 / A47 / A49 / A51 / A5 | Micro-Irrigation Conv. | 32 | 32 |
| | **Ag Pumping and Related End Use Total** | | 148 | 138 |
| **Refrigeration** | R17 / R18 | High-Capacity Condenser | 10 | 10 |
| | R2 | Strip Curtains for Walk-In | 1 | 1 |
| | R52 | Condensate Evaporator | 2 | 2 |
| | **Refrigeration End Use Total** | | 13 | 13 |
| **Greenhouse Heat Curtain Total** | A10 | Greenhouse Heat Curtain | 11 | 11 |
| **Ag Pumping, Refrigeration, and Greenhouse Heat Curtain End Uses** | | | **172** | **162** |
| **AG Miscellaneous End Uses**** | | | **65** | **-** |
| **AEEI PROGRAM TOTAL** | | | **237** | **162** |

*PG&E MDSS Measure Codes

**The miscellaneous end uses are evaluated under Protocol Table C-9. They are not included in this evaluation.

The on-site audits forms are included in Appendix B. The gross impact estimates for each end use are discussed by measure in the following sections.

# 2. Ag Pumping and Related Measures Analysis

## *2.1 Pump Repair*

There were 111 applications for this measure, representing 76 unique customers. In order for pump test results to identify the change in efficiency due to pump repairs, they must (1) be conducted both before and after the repair, and (2) be technically sound tests yielding good data. For example, if a well cannot be sounded for depth or does not have the proper length test section, the test gives poor and misleading results. The evaluation approach minimized cost yet continued to provide credible impact results for this measure by using the PG&E pump test database to carefully select accounts for post-repair pump tests. Only if the pump repair measure had a PG&E pump test performed before the repair, as determined from the pump test database, program applications, and discussions with the grower, was a post-installation pump test performed during the on-site audit. Analysis of the pump test database identified 43 pump tests that met those criteria. A census of these 43 pumps was attempted with 33 completed, good tests. For other pump repair sites, only retention and use information was collected.

The algorithm shown in Exhibit 2.1 was used to determine the energy impacts for pump repairs.

**Exhibit 2.1**
**Pump Repair Energy Impact Algorithm**

$$\text{Impact} = \sum_{i=1}^{111} \text{kWh}_{97,i} * \left(1 - \frac{\text{OPE}_{pre}}{\text{OPE}_{post}}\right)_i$$

Essentially, there were two pieces of information required to apply the impact algorithm to each pump repaired. First, the 1997 kWh for the site must be known for only the specific pump repaired. Second, the pump type and horsepower (hp) must be known to properly apply the second half of the algorithm – the OPE ratio.

On-site audits provided the information used to allocate the billing data usage. The hp of the other pumps on the meter and the percentage of time these pumps operated was gathered. Assuming the pumps were fully loaded when on, the percentage of the kWh used by the repaired pump was calculated. The audit also provided the hp and pump type for correct application of the OPE ratio.

The evaluation team collected post-repair OPE values from 33 pumps. These pumps had pre-repair OPE values already recorded in the PG&E pump test database. To increase the number of actual pre- and post-OPE values, the 1992-1997 PG&E pump test database were analyzed to identify pumps with pre- and post-pump repair results. Since there is a difference in the pre-to-post efficiency possible based on technology (e.g., turbine, centrifugal, or axial flow pump), this data was analyzed by pump type. There was a large enough sample in the pump test database to separate the turbine pumps into two bins – 20-75 hp and over 75 hp. The values for the PG&E pump test database analysis and the evaluation pump tests are shown in Exhibit 2.2

**Exhibit 2.2**
**Ex Post OPE Values**

| Data Source | N of Data | Pump Type | hp Bin* | Pre-OPE | Post-OPE | OPE Ratio |
|---|---|---|---|---|---|---|
| 1997 Evaluation Pump Tests | 7 | Axial/Propeller | All | 0.38 | 0.48 | 0.20 |
| Review of 1992-1997 PG&E Pump Test Database | 18 | | | 0.45 | 0.52 | 0.13 |
| **Weighted Average OPE for Axial/Propeller Pumps** | | | | **0.43** | **0.51** | **0.15** |
| 1997 Evaluation Pump Tests | 2 | Centrifugal, Booster | All | 0.05 | 0.25 | 0.80 |
| Review of 1992-1997 PG&E Pump Test Database | 1 | | | 0.69 | 0.74 | 0.06 |
| **Weighted Average OPE for Centrifugal Booster Pumps** | | | | **0.26** | **0.41** | **0.36** |
| 1997 Evaluation Pump Tests | 3 | Submersible | All | 0.38 | 0.47 | 0.18 |
| Review of 1992-1997 PG&E Pump Test Database | 17 | | | 0.43 | 0.53 | 0.19 |
| **Weighted Average OPE for Submersible Pumps** | | | | **0.42** | **0.52** | **0.19** |
| 1997 Evaluation Pump Tests | 15 | Turbine, Well | 1 | 0.38 | 0.58 | 0.34 |
| Review of 1992-1997 PG&E Pump Test Database | 162 | | | 0.52 | 0.60 | 0.13 |
| **Weighted Average OPE for Deep Well Turbine Pumps from 20-75 hp** | | | | **0.51** | **0.60** | **0.15** |
| 1997 Evaluation Pump Tests | 6 | Turbine, Well | 2 | 0.50 | 0.64 | 0.23 |
| Review of 1992-1997 PG&E Pump Test Database | 48 | | | 0.53 | 0.63 | 0.16 |
| **Weighted Average OPE for Deep Well Turbine Pumps from Over 75 hp** | | | | **0.52** | **0.63** | **0.17** |

There was sufficient data to apply the results by pump type, with the exception of centrifugal pumps. The average turbine pre- and post-efficiency for motors under 75 hp were applied to centrifugal pumps.

For the 31 pumps with known pre- and post-OPE values (33 evaluated pumps minus the 2 centrifugal pumps), the pump-specific pre- and post-repair OPE values were used to determine the impact. All other pumps (80) used the weighted average OPE ratio shown in Exhibit 2.2, based on the pump type and hp.

Pump account number data was collected during the on-site audit to be able to pull the 1997 billing data. However, even with this information, there were eleven accounts with missing kWh data in 1997. For these pumps, the 1996 data was located and used to determine the impact.

The difference in kW both pre- and post-repair was also analyzed using the 1992-1997 PG&E database information to determine if there were demand impacts. On average, there was an increase of 1.3 kW due to the pump repair. However, the standard deviation around that value was large and included zero. The pre- and post-repair kW values were further analyzed using a single-tailed t-test. At the 90% confidence level, there were no significant differences between the pre- and post-repair kW (t=0.001). Because of the results of the t-test, the demand impacts were set to zero for all the pump repair measures. This is consistent with the 1996 PG&E agricultural sector evaluation findings. The gross impacts for pump repair measures are shown in Exhibit 2.3.

**Exhibit 2.3**
**Pump Repair Gross Impacts**

| | Ex Ante | Ex Post | Gross Realization Rate |
|---|---|---|---|
| Energy (kWh) | 3,636,313 | 4,672,255 | 1.28 |
| Demand (kW) | 743 | 0 | 0 |

The ex ante impacts were determined using the 1996 billing data. The total ex ante kWh billed was 34,768,389 kWh for the 111 pumps repaired. This value, from the MDSS, represents the pre-repair pump usage for just the repaired pump. Once the 1997 kWh data were analyzed to obtain the post-repair pump usage for the repaired pumps, it totaled 25,607,561. The decrease in usage from the 1996 year was expected due to the wet weather in 1997. However, based on this, it appears that the ex post impact should have been smaller than the ex ante estimate. This was not the case because of the higher than projected OPE ratio applied for all pumps. The ex ante analysis used two hp bins to determine OPE and did not distinguish between pump types. For comparison purposes only, Exhibit 2.4 compares the OPE values used for the ex ante and the ex post cases in the bins used in the ex ante estimates. These are not the bins used in the ex post analysis; however, Exhibit 2.4 does demonstrate that the ex post OPE values are higher than the ex ante OPE estimates. The OPE ratio difference was the reason for the ex post impacts being higher than the ex ante estimate of impacts.

**Exhibit 2.4**
**Ex Ante and Ex Post OPE Ratios**

| | Bin 1 (20-75 hp) | Bin 2 (Over 75 hp) |
|---|---|---|
| Ex Ante | 0.210 | 0.106 |
| Ex Post | 0.230 | 0.181 |
| N of Ex Post | 55 | 56 |

### *2.2 Low-Pressure Sprinkler Nozzles*

There were five sites rebated for this measure. The low-pressure sprinkler nozzle measure used an approach similar to the ex ante estimates, but used measured data from pump tests. The algorithms used for the demand impacts are shown in Exhibit 2.5.

**Exhibit 2.5**
**Low-Pressure Sprinkler Nozzles Demand Impact Algorithms**

(1) Delta hp = ($GPM_{\text{from pump test}}$) * delta TDH / (3960 GPM-Ft/hp* current OPE)
where TDH = total dynamic head
OPE = operating plant efficiency

(2) Delta hp / acre = (1) above / acres irrigated

(3) Nozzles / acre = nozzles found at site / acres irrigated

(4) Delta kW / nozzle = (2) above * 0.746 kW/hp / (3)

(5) Peak kW / nozzle impact = (4) above * Coincident Diversity Factor of 0.78[1]

Certain assumptions were made during the low-pressure sprinkler nozzle analysis. It was assumed that the OPE of the old and new system was the same if there was no change in the pumping system. If the pump had been retrofitted, the pre-OPE was determined based on the information from the pump repair analysis. It was assumed that the irrigation efficiency (IE) of the old system and the new system was the same. Therefore, there was no assumed difference between the acre-feet (AF) of water pumped in 1997 and what would have been pumped with the old high-pressure sprinkler system. These assumptions result in conservative estimates. The nozzle pressure (shown as "P" in Exhibit 2.6) in pounds per square inch (psi) for the pre- and post-nozzles was based on grower self-reports. The algorithms used to determine site-specific energy impacts for the low-pressure sprinkler systems are shown in Exhibit 2.6.

[1] Appendix A of "Impact Evaluation of Pacific Gas & Electric Company's 1995 Agricultural Energy Efficiency Incentive Programs: Pumping and Related End Use, Indoor Lighting End Use. PG&E Sudy ID Numbers: 329: Pumping and Related End Use. 331: Indoor Lighting End Use", dated March 1, 1997.

**Exhibit 2.6**
**Low-Pressure Sprinkler Nozzle Energy Impact Algorithms**

(1) Post-total dynamic head (TDH) from nozzles = $P_{post}$ (psi) * 2.31 ft/psi

(2) Post-TDH other than nozzles = Actual TDH from pump test – (1) above

(3) Pre-TDH = $P_{pre}$ (psi) * 2.31 ft/psi + (2) above

(4) AF = 1997 kWh / $(kWh/AF)_{from\ pump\ test}$

(5) kWh / $AF_{pre}$ = 1.0241 * (3) above / $OPE_{pre}$

(6) $kWh_{pre}$ = (4) * (5)

(7) kWh Impact = kWh 1997 – (6)

(8) kWh / nozzle impact = (7) / nozzles installed

The evaluation team audited four of the five sites. The impacts for two of the sites were set to zero. One of the two sites was using the nozzles for flow regulation and had not decreased pressure at the pump. The other site increased both the hp and the pressure seen at the pumps, while moving from watering using four sets of nozzles to three sets of nozzles. While the grower was able to water the same acreage in less time, there were no kW or kWh impacts to PG&E.

The ex ante estimate of impacts was used for two other sites. For one of these two sites, the grower was contacted only after many attempts. He indicated that the sprinkler system could not be tested. The grower was reluctant to give any more information. The findings during the on-site audit at the other site indicated that there were impacts at the pump, but no pump test could be performed.

One site had good pump test information. The algorithms shown in Exhibit 2.5 and Exhibit 2.6 were applied to the data collected at this site. This site had a pressure difference of 27 psi, while the ex ante estimate was for 20 psi. This brought the ex post kWh/nozzle impact up to 19.5 kWh/nozzle compared to the 14 kWh/nozzle of the ex ante estimate. The demand impact was also affected by the greater pre/post-pressure difference. The ex post results were 0.020 kW/nozzle and the ex ante estimate was 0.004 kW/nozzle. A comparison of the inputs for the algorithm that creates the kW/nozzle shows why there was such a large disparity between the ex ante and ex post demand impacts. The algorithm is shown in Exhibit 2.7.

**Exhibit 2.7**
**Ex Ante Algorithm for kW/nozzle Impacts**

$$\text{kW/nozzle} = \dfrac{\dfrac{\text{TDH saved} * Q}{3960 * \text{OPE}} * 0.746\ \text{kW/hp}}{\text{nozzles/acre}}$$

where:

TDH = total dynamic head saved
Q = pump flow in gallons per minute per acre
OPE = operating plant efficiency

As mentioned earlier, the ex post analysis had a greater pressure difference and a larger TDH saved (46.2 feet ex ante and 62 feet ex post). At this site the flow was also much greater in the ex post case (7.56 GPM/acre ex ante and 40 GPM/acre ex post). The added flow was due to the pump servicing acreage other than the low-pressure nozzle fields at the same time. The evaluation team decided not to use the results of that one site to help determine the impacts of the two sites without data. The ex ante estimates were conservatively used for the two sites where pump test data could not be collected. The results of the low-pressure sprinkler analysis are shown in Exhibit 2.8.

**Exhibit 2.8**
**Low-Pressure Sprinkler Nozzle Ex Post Impacts**

| | | Ex Ante Impact | | Ex Post Impact | | Realization Rate | |
|---|---|---|---|---|---|---|---|
| Audit | Impact Decision | kWh | kW | kWh | kW | kWh | kW |
| 101 | Use Ex Ante Estimate | 30,250 | 15.0 | 30,250 | 15.0 | 1.00 | 1.00 |
| 120 | Use Ex Post Estimate | 9,800 | 2.2 | 13,670 | 13.9 | 1.39 | 6.41 |
| 135 | Zero Impact | 42,000 | 22.4 | 0 | - | 0.00 | 0.00 |
| 153 | Use Ex Ante Estimate | 50,000 | 11.5 | 50,000 | 11.5 | 1.00 | 1.00 |
| 186 | Zero Impact | 9,590 | 2.1 | 0 | - | 0.00 | 0.00 |
| | Total | 141,640 | 53.2 | 93,920 | 40.4 | 0.66 | 0.76 |

## *2.3 Micro Irrigation Conversion*

The participants for this measure represented 32 applications and 14 unique customers. As shown in Exhibit 1.1, the evaluation team was able to perform audits at all sites and pump tests at most sites.

For the demand impacts, the micro irrigation conversion measure used an approach similar to the low-pressure sprinkler nozzle analysis. The on-site audits determined whether the system ran during peak periods. A coincident diversity factor (CDF) was applied on a site-specific basis. If the site ran 24 hours per day during watering sets, the CDF was set to one. If it was determined that there was a peak period lock out on the metering box or the irrigation sets were for 12 hours or less, the CDF was set to zero. The average CDF for the 32 sites was 0.87.

**Exhibit 2.9**
**Micro Irrigation Conversion Demand Impact Algorithms**

(1) Delta TDH = Pre TDH – Post TDH

(2) kW Impact = (GPM $_{\text{from pump test}}$) * (1) above / (3960 GPM ft/hp* post OPE) * 0.746 kW/hp * CDF

(3) kW Impact / acre = (2) above / acres converted

Micro irrigation system conversion rebates were paid when a customer converted from a sprinkler irrigation system (either high-pressure or low-pressure) to a micro irrigation system. There was one site that converted from a flood irrigation system. The demand and energy impacts at this site were set to zero.

In general, the pumping systems were renovated to allow the micro irrigation to function properly. The impact of the retrofit both decreased the AF of water applied and changed the pumping system. The analysis of the micro irrigation sites used the pump test information in a similar fashion to the low-pressure sprinkler nozzle analysis. The estimated pre- and post-pressure were based on grower self-reports. There were three sites which did not know the pre-retrofit pressure. The average pre-retrofit pressure from the other sites was used (57 psi). One site did not know the post-retrofit pressure. The average of the other sites was used (44 psi).

Questions were asked in the field regarding the previous irrigation system type. The irrigation efficiency value used to determine the AF/yr that would have been applied without the micro irrigation system was determined from two sources: (1) previous Ag evaluation data (irrigation efficiency results for sprinkler systems) and (2) an estimate of the current systems' irrigation efficiency as determined by the experts in the field (and referenced with any current research). Talking these two sources into account, the analysis used a 10% increase in the irrigation efficiency between the pre- and post-retrofit irrigation system.

When a pump was changed out to a different type, the pre-OPE assigned to the pump was based on the previous pump type. For example, if the post-retrofit pump was a turbine booster and the pre-retrofit pump had been a centrifugal pump, the average OPE for "routine" tests within the PG&E pump test database was applied for the pre-retrofit OPE. The on-site audit determined if the post-retrofit pump had been repaired. If so, the OPE difference was based on the pump repair analysis OPE ratio. There were five pumps that had a bowl/impeller pump repair. All were turbine pumps under 75 hp. The current OPE was multiplied by 0.85 (using the OPE ratio of 0.15 from Exhibit 2.2) for the pre-retrofit pump OPE. The site-specific energy impact algorithms are shown in Exhibit 2.10.

**Exhibit 2.10**
**Site-Specific Micro Irrigation Energy Impacts**

(1) Post-total dynamic head (TDH) from system = $P_{post}$ (psi) * 2.31 ft/psi

(2) Post-TDH outside of micro system = Actual TDH from pump test – (1) above

(3) Pre-TDH = $P_{pre}$ (psi) * 2.31 ft/psi + (2) above

(4) $AF_{post}$ = 1997 kWh / $(kWh/AF)_{from\ pump\ test}$

(5) $AF_{pre}$ = $AF_{post}$ * post IE / pre IE

(6) kWh / $AF_{pre}$ = 1.0241 * (3) above / pre OPE

(7) $kWh_{pre}$ = (5) above * (6) above

(8) kWh Impact = $kWh_{pre}$ – $kWh_{post}$

(9) kWh / Acre Impact = (8) above / Acres converted

In a few cases, the system obtained irrigation water from more than one pump. Information was gathered during the on-site audits to determine the total acres covered by the micro irrigation system and the pumps/accounts that fed that system.

The 32 sites with micro irrigation conversion rebates showed much lower ex post energy impacts than predicted by the ex ante estimates. It was not possible to collect good pump test data for all sites. There were six sites to which average kWh/acre (202 kWh/acre) and kW/acre (0.18 kW/acre) impacts were assigned.

The ex post kWh impact is smaller than the ex ante estimate due to lower ex post findings for the acre-foot per acre (AF/Ac) of water applied and the lower pre/post pressure difference. The ex ante estimate assumes an average 2.7 AF/Ac, while the ex post average was 1.3 AF/Ac. The ex ante estimate uses an acreage-weighted, average annual net irrigation requirement with various assumptions, such as 33% of average annual gross rainfall as effective. The ex post findings used the 1997 kWh data for all pumps irrigating the acreage and kWh/AF from the site-specific pump test to determine the AF used on the crop in 1997. The AF value was then divided by the acreage watered by micro irrigation to determine the AF/Ac value.

For the pre/post pressure difference, the ex ante assumes a pressure difference of 36 psi, while the actual average ex post pressure difference for the sites inspected was only 13 psi. Coupled with the lower AF/Ac value, the ex post energy impact was substantially lower than the ex ante estimate. The lower pressure difference also led to lower ex post demand impacts. The results are shown in Exhibit 2.11.

A perusal of the acres paid and irrigated shows that the paid acres and what was found during the on-site audit did not always match up. Often the acres irrigated were greater than what was paid by PG&E. In these cases, a conservative approach was used and only the impact from the paid acres was calculated.

**Exhibit 2.11**
**Micro Irrigation Conversion Ex Post Impacts**

| | | Ex Ante Estimates | | | Ex Post Impacts | | | | Gross Realization Rate | |
|---|---|---|---|---|---|---|---|---|---|---|
| Audit Num | P Measure Code | Paid Acres | kWh | kW | Acres Irrigated | kWh | kW | Coincident kW | kWh | Coin. kW |
| 106 | A45 | 18 | 21,700 | 10 | 18 | - | - | - | - | - |
| 107 | A45 | 25 | 15,624 | 7 | 25 | 1,928 | 2 | 2 | 0.12 | 0.24 |
| 109 | A45 | 100 | 86,800 | 38 | 100 | 7,818 | 13 | 13 | 0.09 | 0.34 |
| 112 | A45 | 30 | 26,040 | 11 | 30 | 321 | 1 | - | 0.01 | - |
| 115 | A45 | 15 | 13,020 | 6 | 23 | - | - | - | - | - |
| 121 | A45 | 15 | 13,020 | 6 | 72 | 3,840 | 4 | 4 | 0.29 | 0.65 |
| 124 | A45 | 22 | 19,096 | 8 | 20 | 5,009 | 5 | - | 0.26 | - |
| 125 | A45 | 50 | 43,400 | 19 | 50 | 21,421 | 6 | 6 | 0.49 | 0.30 |
| 126 | A45 | 6 | 5,208 | 2 | 30 | 3,216 | - | - | 0.62 | - |
| 127 | A47 | 10 | 7,030 | 3 | - | - | - | - | - | - |
| 150 | A45 | 7 | 6,076 | 3 | 24 | 357 | (2) | - | 0.06 | - |
| 179 | A49 | 130 | 106,470 | 49 | 220 | 72,410 | 24 | 24 | 0.68 | 0.49 |
| 180 | A49 | 69 | 56,511 | 26 | 69 | 21,861 | 17 | 17 | 0.39 | 0.67 |
| 187 | A49 | 152 | 124,488 | 58 | 450 | 30,678 | 27 | - | 0.25 | - |
| 210 | A51 | 208 | 92,091 | 36 | 160 | 32,293 | 28 | 28 | 0.35 | 0.78 |
| 211 | A51 | 139 | 137,639 | 54 | 140 | 34,596 | 15 | 15 | 0.25 | 0.28 |
| 214 | A55 | 423 | 175,545 | 84 | 385 | 77,704 | 69 | 69 | 0.44 | 0.82 |
| 222 | A55 | 56 | 23,240 | 11 | 165 | 11,302 | 10 | 10 | 0.49 | 0.90 |
| 235 | A44 | 430 | 264,450 | 184 | 432 | 102,820 | 132 | 132 | 0.39 | 0.71 |
| 236 | A44 | 496 | 305,040 | 213 | 418 | 108,776 | 172 | 172 | 0.36 | 0.81 |
| 237 | A44 | 540 | 332,100 | 232 | 515 | 92,090 | 215 | 215 | 0.28 | 0.93 |
| 238 | A44 | 374 | 230,010 | 160 | 348 | 83,161 | 118 | 118 | 0.36 | 0.74 |
| 239 | A49 | 150 | 171,171 | 79 | 151 | 30,476 | 27 | 27 | 0.18 | 0.34 |
| 240 | A49 | 209 | 253,890 | 118 | 209 | 42,182 | 37 | 37 | 0.17 | 0.32 |
| 241 | A49 | 310 | 125,307 | 58 | 304 | 9,164 | 19 | 19 | 0.07 | 0.32 |
| 242 | A49 | 153 | 122,850 | 57 | 152 | 57,934 | 7 | 7 | 0.47 | 0.13 |
| 243 | A49 | 144 | 117,936 | 55 | 149 | 15,216 | 10 | 10 | 0.13 | 0.18 |
| 244 | A49 | 426 | 348,894 | 162 | 406 | 129,583 | 133 | 133 | 0.37 | 0.82 |
| 245 | A49 | 426 | 348,894 | 162 | 438 | 136,209 | 113 | 113 | 0.39 | 0.70 |
| 246 | A49 | 148 | 121,212 | 56 | 141 | 9,749 | 7 | 7 | 0.08 | 0.12 |
| 247 | A49 | 689 | 564,291 | 262 | 620 | 12,219 | 110 | 110 | 0.02 | 0.42 |
| 248 | A49 | 654 | 535,626 | 249 | 687 | 13,581 | 123 | 123 | 0.03 | 0.49 |
| | | **6,624** | **4,814,669** | **2,478** | **6,951** | **1,167,915** | **1,442** | **1,411** | **0.24** | **0.57** |

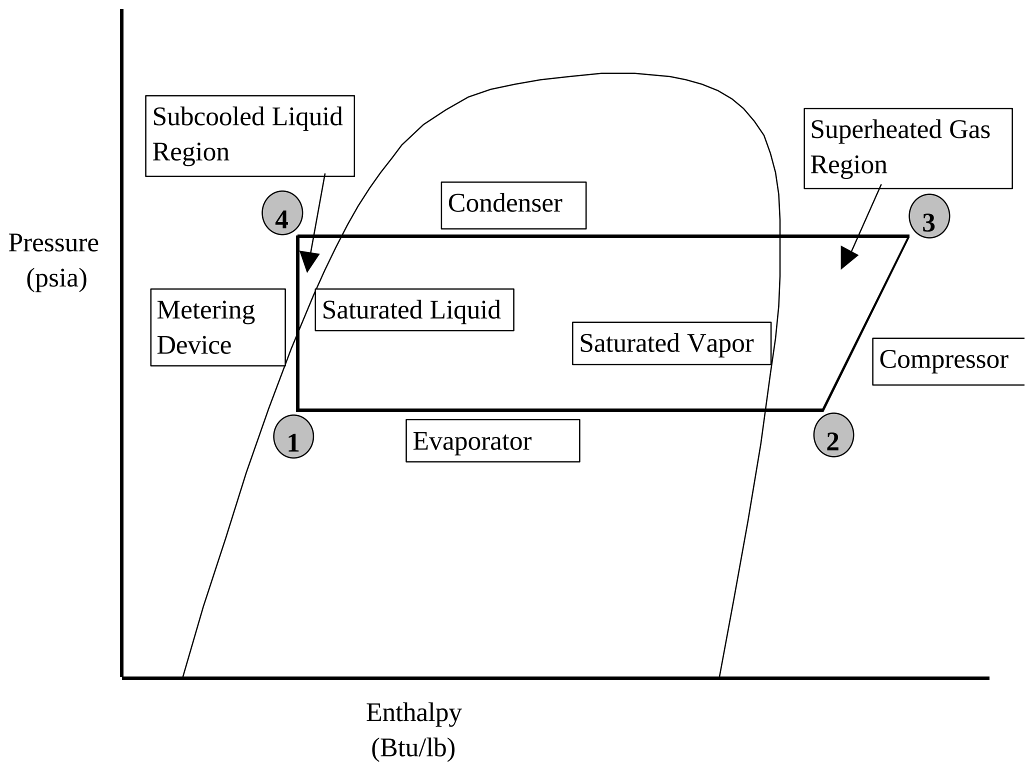
## 3. Refrigeration Analysis

There were three distinct analyses performed for the refrigeration measures. The oversized condensers were 10 of the 13 measures paid during 1997 within the refrigeration end use. Of these ten oversized condensers, nine were installed on ammonia systems and the remaining measure was on a halocarbon system. There were two non-electric evaporative condensers on refrigerator/freezer measures and one strip curtain measure. The analysis performed on the oversized condensers will be discussed first.

### *3.1 Oversized Condensers*

To understand how this measure was analyzed, a short explanation of how a typical refrigeration process occurs is appropriate. Within a standard refrigeration system there are four distinct pieces of equipment: condenser, metering device, evaporator, and compressor. Exhibit 3.1 shows a typical pressure-enthalpy (enthalpy is the heat content within a refrigerant) diagram for a refrigeration system. Each piece of equipment is shown on this diagram based upon where it is used within the refrigeration cycle. The refrigerant goes through four stages, as represented by the four numbers in circles within the diagram. Each stage will be discussed along with how the information from that portion of the diagram was integrated into the analysis.

**Exhibit 3.1**
**Pressure-Enthalpy Diagram**




At point 1, the refrigerant is a both a liquid and gas. As the refrigerant moves through the evaporator, it maintains the same pressure and absorbs heat from the space being cooled. The heat causes the liquid to boil and become a gas. The curved line on the right side of the diagram represents the point where the liquid becomes fully saturated. After the refrigerant gets hotter than the saturated liquid, it is a superheated vapor. Moving from point 1 to point 2, the enthalpy is steadily increasing, as shown in the diagram.

At point 2, the refrigerant is now a superheated gas as it enters the compressor. The compressor increases the pressure of the gas and adds some heat due to the compression (heat of compression). The impacts from the installed measure are realized at the compressor as the oversized condenser decreases the pressure to which the compressor must raise the refrigerant.

In this analysis, the work used to increase the pressure from point 2 to point 3 was determined from *Figure B-6, High Stage Isentropic Work of Compression in Appendix B, Ammonia Refrigeration Application Data*, *Ammonia Data Book*, *December*, *1992*. This table provided the work of compression (in Btu/lb.) required for a typical ammonia system to move from a specific saturated vapor suction temperature to a specific saturated vapor discharge temperature. (From point 2 at the saturated vapor line to point 3 at the saturated vapor line.) However, before the saturated temperatures could be input into this table, they needed to be determined. The suction (point 2) and condensing (point 3) pressures were known by the plant managers. These two pressures were collected for the maximum and average pressures seen both pre- and post-retrofit. Although the exact superheat temperatures are not known at points 2 and 3, the pressure is constant at both the suction and condensing points. Therefore, if the pressure is known, the saturated temperature can be determined from a thermodynamic property table. For this analysis, a pressure/temperature table was used to determine the saturated temperatures at the provided atmospheric suction and condensing pressures for both the pre- and post-retrofit conditions.

From point 3, the refrigerant goes through the condenser. Within the condenser, it steadily gives up heat to the atmosphere and condenses from a gas to a liquid. The condenser generally continues to cool refrigerant past the point were the gas is completely a liquid (the saturated liquid line). The refrigerant is now a sub-cooled liquid at point 4.

The refrigerant then moves through a metering device from point 4 back to point 1. This device decreases the pressure, but keeps the same amount of heat (enthalpy) within the refrigerant. The refrigeration cycle is complete.

This short description of a refrigeration cycle does not take into account the real-world losses associated with any type of refrigeration cycle. It assumes perfect (isentropic) compression and perfectly functioning pieces of equipment. These assumptions were used in the analysis.

The kW impact for this measure was determined as shown in Exhibit 3.2.

**Exhibit 3.2**
**Refrigeration Demand Impact Algorithm**

$$\text{kW} = \frac{\text{Work of Compression} * \text{Mass Flow} * \text{Tons of Refrigeration} * \text{Conversion from Btu/hr to kW}}{\text{Efficiency of Motor}}$$

$$\text{kW} = \frac{\frac{\text{Btu}}{\text{lb}} * \frac{\text{lb}}{\text{hr - ton}} * \text{tons} * \frac{1\,\text{kW}}{3413\,\text{Btu/hr}}}{h}$$

The average kW reduction was determined and the hours of operation were applied to determine the kWh impacts, as shown in Exhibit 3.3 The hours of operation were gathered on site from the plant manager.

**Exhibit 3.3**
**Refrigeration Energy Impact Algorithm**

$$\text{kWh savings} = \text{kW savings} * \text{Hours of operation}$$

The analysis used information gathered during the on-site audits to determine the inputs for Exhibit 3.2. As mentioned earlier, the work of compression was calculated from a table based upon the saturated suction and condensing temperatures.

Mass flow was also calculated. The refrigerant will flow at different rates based upon the saturated suction and condensing temperatures. *Figure B-11, High Stage Mass Flow Rate per Ton in Appendix B, Ammonia Refrigeration Application Data, Ammonia Data Book, December, 1992* was used to estimate the flow of refrigerant at the same suction and condensing temperatures used for the work of compression. This table provided the mass flow in lb./min-ton. When the mass flow is multiplied by 60 minutes per hour and then by the tons of refrigeration obtained, the result is a value of lb./hour of refrigerant.

The next input, tons of refrigeration, was determined in two different ways in the analysis. The first way was to ask the manager the total refrigeration capacity of the system. If this was known and the percentage of capacity used during each period provided, then that specific tons of refrigeration was used in the analysis. Five of the ten sites used this approach. The second way (if the manager did not know the total refrigeration capacity) was to use *Figure B-8, High Stage Isentropic Power Per Ton in Appendix B, Ammonia Refrigeration Application Data, Ammonia Data Book, December, 1992*. This table provides a hp per ton based upon the saturated discharge and suction temperatures. However, the efficiency of compression is also needed. Since this can vary by the compression ratio (an unknown value), the average compression efficiency was used. This value (0.705) was determined from *Figure B-10, Typical Adiabatic Compression Efficiency in Appendix B, Ammonia Refrigeration Application Data, Ammonia Data Book, December, 1992*. The compression efficiency was multiplied by the hp available and then divided by the hp/ton to get the tons of refrigeration at given times. This is shown in Exhibit 3.4.

**Exhibit 3.4**
**Tons of Refrigeration If Only hp Known**

$$\text{Tons} = \frac{\text{Compression Efficiency} * \text{hp available}}{\text{hp/ton}}$$

The last input to determine for the kW level was motor efficiency. The motors used for the compressors have an efficiency that can vary from 0.75 to 0.98, depending on the size and age of the motor. Reciprocating compressors tend to be 100 hp or smaller. Screw compressors are larger, with motors up to 700 hp. The efficiency of the motors was divided into reciprocating compressor motors (125 hp and under) and screw compressor motors (over 125 hp). Standard efficiencies were averaged for these motors from data within MotorMaster+[2]. The efficiencies used were 0.91 for reciprocating motors and 0.95

[2] MotorMaster+, Version 1.0. Washington State Energy Office, Department of Energy, United States of America, 1996.

for screw motors. Through converting the Btu/hr to kW and applying the efficiency of the motor, the estimated demand of the compressors was calculated for various pressures for pre- and post-retrofit.

In all but one case, the tons of refrigeration between the pre- and post-retrofit case was kept constant. It was assumed that the amount of refrigeration provided before the retrofit was adequate and that there would be no more refrigeration required after the retrofit. However, there was one case in which there was a clear amount of refrigeration available (and used) after the retrofit that was not available prior to the retrofit. This site had different tonnage applied to the pre- and post-retrofit cases.

In order to check the tons of refrigeration input applied at each site with another piece of data, the 1997 kWh data from PG&E were used to back out an estimated tons used. This was done by using the compressor hp from the PG&E ex ante estimates or the compressor hp gathered on site. The pre-retrofit condenser fan power for all condensers was not known, therefore an average of 7.5% of the compressor hp was used. Similarly, 25% of the condenser fan hp was set for the condenser pump hp. The evaporator fan hp was unknown and set equal to the condenser fan hp. The compressor, condenser fan, condenser pump, and evaporator fan hp were summed together and converted to kW to provide an estimate of the connected load on an account. The total pre-retrofit condensing tons of refrigeration was known from the PG&E ex ante estimates. The total pre-retrofit kW was divided by the tons of refrigeration to provide a kW/ton estimate. The annual kWh was then divided by this value to provide a ton-hours of refrigeration for the year. The average tons used per year was determined by dividing ton-hours by the number of hours in the year (8,760). This is shown in Exhibit 3.5. It was realized that the kW/ton value did not take into account any current load from the new condenser while the 1997 kWh had that load. However, the check was to used to assess reasonableness only and was not expected to be highly accurate. This method assumed that the only loads on the specified account are the refrigeration pieces of equipment. At some sites, this was clearly not the case.

**Exhibit 3.5**
**Cross-Check of Tons of Refrigeration**

$$\text{Average tons} = \frac{\text{1997 kWh}}{\text{kW/ton}_{\text{pre}}} = \frac{\text{ton - hrs}}{\text{8,760 hrs}}$$

The calculated average tons using Exhibit 3.5 was compared to the average tons as calculated in the analysis (labeled “current method” in Exhibit 3.6). As shown in Exhibit 3.6, four of the comparisons were quite close (R02, R07, R102, R104). One site (R05) obviously had many other loads on the meter than the current refrigeration system. One site (R105) originally had calculated the average tons with the current method as 251 tons of refrigeration used. This was quite a bit higher than estimated using the 1997 kWh, and another check was used to determine the reasonableness of the tons of refrigeration. Because the energy impacts as a percentage of the 1997 kWh were quite high with the 251 tons of refrigeration, the analysis decreased the tons of refrigeration to 115 tons for the impact calculation. One site (R06) had no kWh billing which could be located in the billing data. The last three sites (R01, R101, and R103) used a conservative tons of refrigeration within the analysis as calculated from the current method.

**Exhibit 3.6**
**Average Tons Per Year Results**

| | Pre-Retrofit Data | | | | | | |
|---|---|---|---|---|---|---|---|
| Site | Condenser tons of Refrigeration | hp/ton | kW/ton | 1997 kWh | Avg tons per hour using kWh | Current Method Avg Tons | Notes |
| R01 | 423 | 0.74 | 0.55 | 799,040 | 165.5 | 96.5 | Savings as percentage of 1997 is reasonable, therefore kept analysis as calculated |
| R02 | 48.8 | 1.06 | 0.79 | 194,480 | 28.2 | 28.7 | Savings as percentageage of 1997 is reasonable, therefore kept analysis as calculated |
| R05 | 2,533 | 0.97 | 0.73 | 12,355,200 | 1,944.3 | 285.1 | This site is very large and has many more loads on the meter than known - analysis stands as calculated |
| R06 | 2,738 | - | - | - | - | 579.8 | This site has missing kWh data in the information from PG&E, analysis stands as calculated |
| R07 | 639 | 1.31 | 0.98 | 1,816,480 | 212.1 | 230.5 | This site has unknown pre-retrofit condenser capacity since the page is missing in the hard copy, used the post-retrofit capacity multiplied by 90% - analysis stands as calculated since savings as percentage of 1997 kWh is reasonable |
| R101 | 1,911 | 0.84 | 0.63 | 10,584,000 | 1,922.3 | 1,038.8 | Savings as percentage of 1997 is reasonable and this value is conservative, therefore kept analysis as calculated |
| R102 | 307.5 | 0.91 | 0.68 | 562,665 | 94.9 | 95.0 | Analysis stands as is based on the values shown here and the changes at the site, even though the savings are a high percentage of 1997 kWh |
| R103 | 120.8 | 1.95 | 1.46 | 1,393,680 | 109.3 | 66.7 | Conservatively using the tons of refrigeration as calculated in analysis, not from kWh - analysis stands as calculated |
| R104 | 1,120.8 | 1.16 | 0.87 | 2,481,600 | 327.4 | 330.9 | Analysis stands as calculated based on the values shown here and reasonable savings as a percentage of 1997 kWh |
| R105 | 292 | 1.34 | 1.00 | 993,840 | 113.4 | 115.0 | Decreased the tons of refrigeration to 115 in the analysis based on this and the estimated savings as a very high percentage of 1997 kWh, had been avg. 250.7 tons of refrigeration using information from site |

Once the kWh impacts were determined, another check of reasonableness was applied by using the 1997 kWh data. The impacts as a percentage of the total account kWh was calculated and analyzed. The results are shown in Exhibit 3.7. The impact varied from 2.1% to 28.5% of the 1997 kWh. The notes section indicates the reasoning of the evaluation team.

**Exhibit 3.7**
**Impact as Percentage of 1997 kWh Results**

| Audit ID | 1997 Annual kWh | Ex Post Iimpact | Ex Post as Percent of 1997 kWh | Notes |
|---|---|---|---|---|
| R01 | 799,040 | 55,320 | 6.9% | Reasonable percentage of 1997 kWh and tons of refrigeration used was conservative, analysis savings stand as calculated. |
| R02 | 194,480 | 4,329 | 2.2% | Reasonable percentage of 1997 kWh and tons of refrigeration are close between the two methods of determining that value, analysis savings stand as calculated. |
| R05 | 12,355,200 | 659,398 | 5.3% | Analysis savings stand as calculated. |
| R06 | | 477,763 | - | No kWh data, analysis stands as calculated |
| R07 | 1,816,480 | 37,902 | 2.1% | Reasonable percentage of 1997 kWh, analysis savings stand as calculated. |
| R101 | 10,584,000 | 613,622 | 5.8% | Reasonable - analysis stands as calculated |
| R102 | 562,665 | 105,526 | 18.8% | Tons cooling match between two ways of getting that data, there was a large pressure differential pre vs. post, and the site increase the suction pressure post, so the analysis stands as calculated |
| R103 | 1,393,680 | 396,733 | 28.5% | Reasonable since previously couldn't get all refrigeration out of system and now running at lower capacity, conservatively using tons from analysis, not from 1997 kWh data |
| R104 | 2,481,600 | 86,433 | 3.5% | Reasonable percentage of 1997 kWh and tons of refrigeration are close between the two methods of determining that value, analysis savings stand as calculated. |
| R105 | 993,840 | 111,226 | 11.2% | Decreased the tons cooling based on 1997 kWh data for the analysis, used the average tons of 115 as input to analysis tool rather than 251 |

The results of the kW and kWh analyses for the refrigeration end use are shown in Exhibit 3.8. Audits R03, R04, and R08 are discussed in the following sections.

**Exhibit 3.8**
**Refrigeration Ex Post Impacts**

| | Ex-Ante | | Ex-Post | | Gross Realization Rate | |
|---|---|---|---|---|---|---|
| Audit ID | kWh | kW | kWh | kW | kWh | kW |
| R01 | 143,321 | 25.6 | 55,320 | 10.8 | 0.39 | 0.42 |
| R02 | 7,392 | 1.3 | 4,329 | 1.1 | 0.59 | 0.81 |
| R03 | 9,178 | 1.0 | 0 | 0 | 0 | 0 |
| R04 | 3,362 | 0.2 | 0 | 0 | 0 | 0 |
| R05 | 330,882 | 59.1 | 659,398 | 39.0 | 1.99 | 0.66 |
| R06 | 667,869 | 119.3 | 477,763 | 73.1 | 0.72 | 0.61 |
| R07 | 99,417 | 17.8 | 37,902 | 8.9 | 0.38 | 0.50 |
| R08 | 1,681 | 0.1 | 1,681 | 0.1 | 1.00 | 1.00 |
| R101 | 680,749 | 121.6 | 613,622 | 70.0 | 0.90 | 0.58 |
| R102 | 46,502 | 8.3 | 105,526 | 12.0 | 2.27 | 1.45 |
| R103 | 136,705 | 14.8 | 396,733 | 45.3 | 2.90 | 3.06 |
| R104 | 156,240 | 27.9 | 86,433 | 12.2 | 0.55 | 0.44 |
| R105 | 109,400 | 19.5 | 111,226 | 12.7 | 1.02 | 0.65 |
| Total | 2,392,698 | 416.4 | 2,549,933 | 285.3 | 1.07 | 0.69 |

The ex post energy impacts for oversized condensers were higher than the ex ante estimates while the demand impacts were less. The ex post analysis resulted in a lower average tons of compression total heat rejected (THR). The ex ante average value was 789 tons THR while the ex post average value was 351 tons THR. However, the ex post estimated full load operating hours were higher (4,571 ex post versus 3,030 ex ante). Additionally, the ex post analysis had a slightly greater temperature difference pre-to-post than the ex ante (15.1 ex post versus 11.3 ex ante), leading to greater impacts.

There were three sites that had estimated an ex ante penalty due to excess fan use. For these three sites, the excess kW as estimated from the ex ante paperwork was simply subtracted from the estimated kW impacts prior to multiplying the hours of use.

The differences were not surprising since the evaluation used the actual average operating pressures found at each site to determine the tons of refrigeration used, while the ex ante estimate used the maximum possible tons of heat rejection between the pre- and post-retrofit estimate at design temperatures. These findings also explain why the ex post demand impacts are less than the ex ante estimates.

### *3.2 Non-Electric Condensate Refrigerators/Freezers*

There were two sites that installed this measure. One installed just a refrigerator while the other installed both a refrigerator and freezer. The make and model numbers were gathered on site and the manufacturers of the equipment were contacted to determine if the condensate was actually non-electric. At the site with just the refrigerator, the manufacturer used air funneled around the compressor to defrost the evaporator. At the other site, the manufacturer used electric resistant coils to defrost. A technical engineer at this manufacturer was queried specifically regarding what they used. It was determined that the defrosting device pulled around 300 watts and that they don't make any models which use hot gas defrost. Therefore, the impacts were set to zero for this site. The resulting impacts are shown as line R04 and R08 in Exhibit 3.8.

### *3.3 Strip Curtains*

One site installed strip curtains. This site did not use the strip curtains as expected in the ex ante estimate. The ex ante estimates assumed that strip curtains are placed between a refrigerated walk-in and a conditioned space. At this site, the strip curtains were placed on an outside door between the outside and an unconditioned warehouse. The warehouse shared interior walls with refrigerated storage space. The curtains were installed to decrease the wind through the space and decrease the temperature within the unconditioned warehouse. Once the plant manager realized that he could refrigerate the warehouse space in the evenings, he used it about three times per week to store produce. The unconditioned warehouse was brought down to 34°F by closing all outside doors and opening up large doors between the refrigerated and unconditioned spaces.

Based on assumptions within the analysis and how the space was used during 1997, the impacts from the installation of the strip curtains were equal to or less than the energy used to refrigerate the unconditioned warehouse. The ex post impacts were set to zero as shown in line R03 of Exhibit 3.8.

## 4. Greenhouse Heat Curtain Analysis

There were eleven applications for greenhouse heat curtains paid in 1997. The applications represent nine different customers. All greenhouses were audited for this evaluation.

### *4.1 Greenhouse Heat Curtain Overview*

The greenhouses were constructed of many different materials, from glass to fiber-reinforced polyester to polyethylene film. The majority were multi-span buildings with many peaks. The heat curtains were installed to reduce the therm usage of natural gas heaters by minimizing the heated area and decreasing heat loss from the greenhouses at night. However, while night time heating is the more common use, heat curtains can also be used during the day to control day length, shade crops, and reduce daytime temperatures within the greenhouse. Many of the installed heat curtains were used for daytime shading.

The curtains were thin, movable and attached to the greenhouse using various mechanisms. Research indicated that, in many areas of the U.S., 80% of the energy for heating of single-glazed structures is required at night.[3] Therefore, insulation that can allow for daytime sunlight and keep out night time cold should be moveable. The heat curtain measure, as implemented by PG&E, required that tracks and a motor to deploy the equipment be included. All heat curtains met this requirement.

The heat curtains were most often placed from the join between the roof and wall and at a slight angle upward into the middle of the peak. When closed, the curtain created a "new" ceiling which was much lower.

While the curtains can be deployed during the day, most of the actual therm energy impacts occur at night. The impacts were dependent on the construction of the building, the infiltration of cold air into the greenhouse, how the heat curtain was installed, and the efficiency of the natural gas heater. Based on previous experience, the determination of the efficiency of the heaters in greenhouses could be quite difficult. Therefore, for this evaluation, the efficiency was set at 70% for either individual heaters in the greenhouses or a central boiler. This efficiency is lower than the minimum efficiency (75% for central steam boiler and 74% unit heaters) set by the California Energy Commission (CEC) and accounts for the age of the units and piping losses. The actual temperatures required in the greenhouse were dependent on the crop and varied from 45° F to 85° F. The impacts for heat curtains were determined using the algorithms shown in Exhibit 4.1 and Exhibit 4.2.

**Exhibit 4.1**
**Heat Curtain Impact Algorithm**

$$\Delta Therms = \frac{\Delta Q_t * AnnualHrs * C1}{h}$$

Where:

| | | |
|---|---|---|
| $\Delta Q_t$ | = | Change in heat loss, Btu/hr |
| Annual Hrs | = | Annual Hours in Use, hr |
| C1 | = | Conversion for Therms, 1 therm/100,000 Btu |
| $\eta$ | = | Efficiency of heater, unitless |

The change in the heat loss of the greenhouse due to the addition of the heat curtain ($Q_t$) was determined by both the heat loss due to conduction (heat migrating through the materials from the higher temperature inside to the lower temperature outside) and the heat loss due to infiltration (heat loss through open areas in the construction). These two heat losses were determined as shown below in Exhibit 4.2.

[3] Energy Conservation for Commercial Greenhouses, Northeast Regional Agricultural Engineering Service, NRAES-3, July, 1989.

**Exhibit 4.2**
**Heat Loss Algorithm**

$$\Delta Qt = \left[\left(\sum_{i=1}^{n} U_i * A_i\right) * CM + c_p * Vol * ACH\right]_{pre} * \Delta T - \left[\left(\sum_{i=1}^{n} U_i * A_i\right) * CM + c_p * Vol * ACH\right]_{post} * \Delta T$$

Where:

| | | |
|---|---|---|
| $U_i$ | = | Heat transfer coefficient of each material *i*, Btu/hr-ft$^2$-°F |
| $A_i$ | = | Area of each material *i*, ft$^2$ |
| CM | = | Construction Multiplier based on frame type, unitless |
| ΔT | = | Average inside to outside temperature difference, °F |
| $c_p$ | = | volumetric specific heat of air, 0.018 Btu/ ft$^3$-°F |
| Vol | = | Volume of the greenhouse, ft$^3$ |
| ACH | = | Air changes per hour, changes/hr |

The impacts determined were site specific and, in some cases, greenhouse specific. Each element within the algorithms used to determine impacts is covered in detail in the next section.

## *4.2 Greenhouse Algorithm Details*

### 4.2.1 Heat Loss Algorithm

The details of the heat loss algorithm (Exhibit 4.2) are presented first. There were thirteen materials to which a U-value was assigned. The U-values were based on page 8 of *Energy Conservation for Commercial Greenhouses*, Northeast Regional Agricultural Engineering Service, NRAES-3, July, 1989. This document states that almost all single-layer materials have a heat transfer (U-value) between 1.0 and 1.2 Btu/hr-ft$^2$-°F and almost all double layer materials have a U-value between 0.6 and 0.7 Btu/hr-ft$^2$-°F. The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) 1995 HVAC Applications Handbook was also referenced to determine U-values for the materials. If the ASHRAE Handbook had a more specific value than the NRAES-3, it was used. The materials found during the on-site audits, the assigned U-values, and where the U-values came from are shown below in Exhibit 4.3.

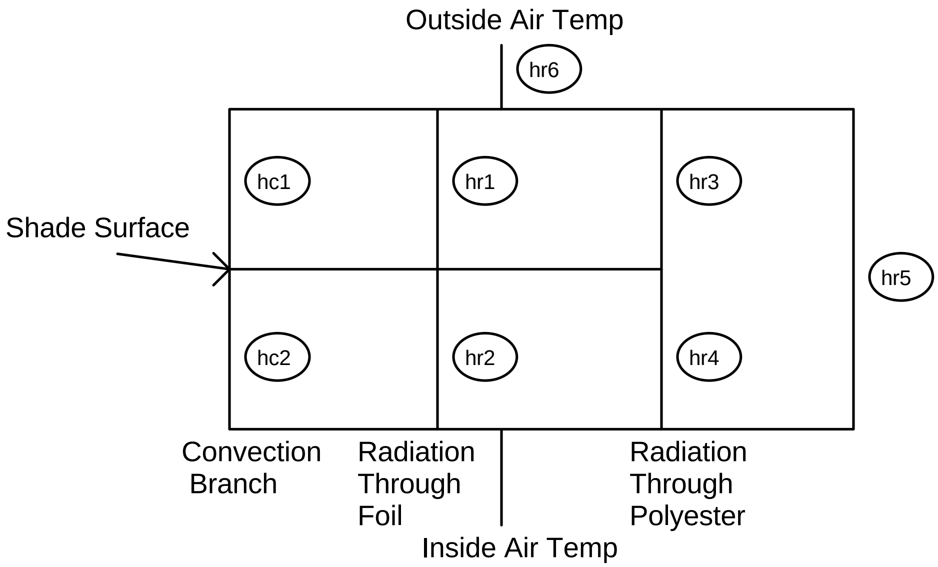
**Exhibit 4.3**
**U-values for Greenhouse Materials**

| Material | U-value | Notes |
|---|---|---|
| 4 mil Polyethylene Film - double with air gap | 0.65 | From Energy Conservation for Commercial Greenhouses |
| 4 mil Polyethylene Film - single | 1.20 | From ASHRAE Applications Handbook, p.20.9, Table 1 |
| 6 mil Polyethylene Film- single | 1.15 | From ASHRAE Applications Handbook, p.20.9, Table 1 |
| Acrylic | 1.10 | From Energy Conservation for Commercial Greenhouses |
| Double-pane Glass | 0.70 | From ASHRAE Applications Handbook, p.20.9, Table 1 |
| Fiber-reinforced Polyester | 1.20 | From ASHRAE Applications Handbook, p.20.9, Table 1 |
| Fiber-reinforced Polyester and 6 mil Poly | 0.59 | Summing R values and inversing |
| Laminated Acrylic/Polyester Film | 0.72 | From ASHRAE Applications Handbook, p.20.9, Table 1 |
| Polycarbonate | 1.10 | From Energy Conservation for Commercial Greenhouses |
| Polycarbonate with 1.25" thermax sheathing | 0.12 | Polycarbonate + R of 5.8 per inch for Thermax Sheathing |
| Single-pane Glass | 1.13 | From ASHRAE Applications Handbook, p.20.9, Table 1 |
| Single-pane Glass with 1.25" thermax sheathin | 0.12 | Single Pane Glass + R of 5.8 per inch for Thermax Sheathing |
| Weatherable polyester film | 1.20 | From ASHRAE Applications Handbook, p.20.9, Table 1 |

The areas for each type of material were determined from the information gathered on site. More than one site had three walls of one type of material and the fourth of a different type of material. Each different material's U-value was determined and then multiplied by the corresponding area to create a total UA for the greenhouse.

The total UA was determined with and without the heat curtain in place. All heat curtains, except one, were constructed by a company called Ludwig Svensen. These heat curtains are of a porous weave with differing levels of aluminum incorporated into the weave. The aluminum reflects the heat back into the space. However, because of how the material is made, there is no specific U-value for the material. Instead, a complex heat transfer circuit was used to determine the heat transfer conductance through the roof with the screens in place. The analysis for the heat transfer was taken directly from *Energy Saving Using Greenhouse Shading/Insulating Screens Report*, CEC Contract #400-92-010, November, 1994. The work in this report had been performed by the Irrigation Training and Research Center in California Polytechnic State University. The heat transfer circuit used is shown below in Exhibit 4.4.

**Exhibit 4.4**
**Heat Transfer Circuit**




Where:

hc1 = convection conductance between screen and roof glazing
hc2 = convection conductance between inside air and screen
hr1 = radiation conductance between the foil portion of the screen and the roof glazing
hr2 = radiation conductance between the foil portion of the screen and the ground/biomass
hr3 = radiation conductance via clear polyester part of the screen
hr4 = radiation conductance via clear polyester part of the screen (equal to hr3)
hr5 = radiation conductance directly from ground/biomass to the roof glazing via clear polyester portion of screen
hr6 = heat transfer conductance from inside surface of roof glazing to the outside environment

The overall resistance of the roof with the heat curtain in place was determined using the equation shown in Exhibit 4.5.

**Exhibit 4.5**
**Overall Resistance Equation**

$$\text{Rwithscreen} = \frac{1}{hr5 + \frac{1}{\frac{1}{hc1 + hr1 + hr3} + \frac{1}{hc2 + hr2 + hr4}}} + \frac{1}{h6}$$

The radiation portion of the equation varied based on the percentage of foil within the screen. An engineer at Ludwig Svensen clarified the differences between the labeling of the heat curtain material and the percentage of aluminum in the foil. While not exact, each heat curtain material was assigned a percentage of aluminum. The hr6 value was determined based on the specific roofing material at the site and the overall resistance was calculated for each different roofing/heat curtain combination. The resistance was then inverted to determine a U-value for the roof with heat curtain in place for each greenhouse. The one material which was not a Ludwig Svensen material (a black aluminum shade) was assigned a value similar to the material with the least amount of aluminum, and, therefore, created a conservative estimate of resistance. The results of the specific roof/heat curtain combinations are shown in Exhibit 4.6.

**Exhibit 4.6**
**Roof U-value With and Without Heat Curtain**

| Roof | U without heat curtain | Heat Curtain | U with heat curtain |
|---|---|---|---|
| 4 mil Polyethylene Film - double with air gap | 0.65 | LS14 | 0.39 |
| Fiber-reinforced Polyester | 1.20 | LS14, West Half, LS15, East Half | 0.49 |
| Fiber-reinforced Polyester | 1.20 | LS15 | 0.44 |
| Fiber-reinforced Polyester | 1.20 | LS15F | 0.60 |
| Fiber-reinforced Polyester | 1.20 | LS15F at 50% and LS15 at 50% | 0.51 |
| Fiber-reinforced Polyester | 1.20 | LS16 | 0.45 |
| Fiber-reinforced Polyester | 1.20 | LS17 | 0.41 |
| Polycarbonate | 1.10 | LS15 | 0.43 |
| Polycarbonate | 1.10 | LS15F | 0.57 |
| Single-pane Glass | 1.13 | LS15 | 0.43 |
| Single-pane Glass | 1.13 | LS15F | 0.58 |
| Single-pane Glass | 1.13 | PH98 | 0.58 |

The frame type affects the heat conductance of the structure. The greenhouses had wood, aluminum and galvanized steel framing. A construction multiplier was assigned based on the type of frame. These are shown in Exhibit 4.7 below. The total UA was multiplied by the construction multiplier to determine the overall UA of the structure.

**Exhibit 4.7**
**Construction Multipliers**

| Frame Type | Construction Multiplier |
|---|---|
| Wood | 1.00 |
| Galvanized Steel | 1.03 |
| Aluminum | 1.05 |

The volume of the greenhouse was calculated both with and without the heat curtain in place based on data collected at the sites. The air changes per hour (ACH) were assigned based on the ASHRAE HVAC Applications Handbook (p. 20.9, Table 3). The ACH varied by new or old construction and good or poor maintenance. Greenhouses which were older than five years were considered old. Determination of good or poor maintenance was based on the auditors' judgement. The ACH values applied are shown in Exhibit 4.8.

**Exhibit 4.8**
**ACH Values**

| Age and Maintenance | ACH |
|---|---|
| Old (>= 5 years), Poor | 3.0 |
| Old (>= 5 years), Good | 1.5 |
| New (< 5 years), Good | 1.0 |

The ACH will change when the heat curtain is in place. However, most of the heat curtains left areas open for ventilation. Because of this, the ACH with heat curtain in place was decreased only by the average decrease in volume (12%).

### 4.2.2 Heat Curtain Impacts Algorithm

The change in heat loss, as calculated in Exhibit 4.2, was multiplied by the site-specific annual hours in use. These hours were determined based on the WYEC2 weather data for the zone in which the site was located and the specific greenhouse temperature set point. One site was in CEC Zone 1; one site was in CEC Zone 2; six sites were in CEC Zone 3; and one site was in CEC Zone 4. These zones are based on the CEC Nonresidential Manual, updated March 1996.

Information gathered during the on-site audit was used to determine a thermostat set point and hours of use of the heat curtain. A non-typical use of the deadband concept was used in the analysis. The heating did not come on unless the temperature outside was three degrees lower than the thermostat set point. While the typical use of a deadband is the range in which the thermostat turns itself on and off, based on the sensed temperature, this analysis did not employ a dynamic model which could determine the heat flows through the space to the thermostat. The value of three degrees was set based on engineering judgement.

Each hour of the year was analyzed to determine first, if the heat curtain was expanded (open and working as a heat barrier), and second, if the temperature outside was less than the set point. If both criteria were met, the outside temperature was subtracted from the set point to determine a delta temperature. A summation of the hours when the heat curtain was expanded provided the annual hours of operation. The average delta temperature was used for both the pre- and post-retrofit calculation in Exhibit 4.2. The analysis, then, provided impacts based on typical weather.

The annual hours of operation varied from a low of 238 hours to a high of 5,685 hours, with a mean of 3,651 hours of use. The average delta temperature ranged from a low of 5.8° F to a high of 27.4° F, with a mean of 12.1 °F.

The ex post impacts are shown in Exhibit 4.9.

**Exhibit 4.9**
**Greenhouse Heat Curtain Ex Post Impacts**

| Audit | Ex Ante | Ex Post | Gross Realization Rate |
|---|---|---|---|
| 303 | 51,836 | 11,159 | 0.22 |
| 301 | 168,525 | 108,476 | 0.64 |
| 302 | 27,821 | 35,653 | 1.28 |
| 304 | 15,246 | 4,229 | 0.28 |
| 305 | 48,232 | 42,093 | 0.87 |
| 306 | 17,035 | 16,649 | 0.98 |
| 307 | 122,359 | 76,294 | 0.62 |
| 308 | 29,878 | 25,057 | 0.84 |
| 309 | 59,754 | 1,204 | 0.02 |
| 310 | 11,952 | 366 | 0.03 |
| 311 | 27,988 | 58,936 | 2.11 |
| Total | 580,625 | 380,118 | 0.65 |

### *4.3 Ex Post/Ex Ante Discrepancies*

The ex post findings of impacts were less than the ex ante estimate of impacts. The ex ante estimate of impacts used an average savings of 0.60 therms per installed square foot of heat curtain. The ex post analysis average impacts was 0.50 therms per installed square foot of heat curtain. Included in the therms/ft$^2$ value are all the differences between the ex ante and ex post analysis method and input assumptions. Some of these inputs are shown in Exhibit 4.10.

**Exhibit 4.10**
**Ex Ante and Ex Post Heat Curtain Inputs**

| Input Item | Ex Ante | Ex Post |
|---|---|---|
| Night Time Temperature | 65° F | Varied between 45° F and 85° F with an average of 60° F |
| Air Changes with Heat Curtain | 33% reduction | 12% reduction |
| Roof U-value Pre | 1.23 | 1.02 |
| Roof U-value Post | 0.45 | 0.50 |

The other reason for the difference in ex post impacts was the fact that, at some sites, there were fewer square feet installed than originally rebated. There were about 12% fewer square feet installed than rebated.

The ex post impacts averaged 38% of the pre-retrofit estimated therm usage. While the pre/post-therm usage could not be correlated with billing data reductions because many sites had multiple greenhouses on one meter, billing data were looked at for some of the sites. The estimated usage for a few of the specific greenhouses were not unreasonably large or small compared to the actual therm usage. As such, while the gross realization rate was relatively low, the evaluation team believes the analysis appropriately reflects the actual impacts.

This concludes the engineering appendix for the 1997 Agricultural Programs evaluation.

# Appendix B
# Final On-site Instrument

# *1995 AG PROGRAM RETENTION QUESTIONAIRE*

Customer Name

Business Name

Customer Addres

City

Phone or

New Contact Name ______

New Phone Num?: ______ Acct Code

PGE Audit Acct

New PGE Acct ______

Audit Num: 600

Orig CCS Surveyor ______

Division: ______

Assigned To: ______

Old Audit ID ______

Date Customer Talked To: ______

Is a Site Visit Necessary? 0

Date Site Visited ______

Date Completed: ______

| **1995 Measure:** | **Measure Code** | **Measure Description** |
|---|---|---|
| 0 **Custom Audit** | | |
| 0 **Pump Audit** | | |
| 0 **Lighting Audit** | | |

**Location Description - Custom, Pump Repair**

**Location Description - Lighting**

**Is the 1995 measure still present?** **( yes / no )** ______

**If not present, explain why not**

______

**Was this measure used in 1998?** **( yes / no )** ______

**If no, explain why not?**

______

**Approximate date removed from service** ______

## *Continue for Lighting Audits ONLY*

| **Num Fixtures** | **Group Descriptions** | **Lamp Fixture** | **Watt** |
|---|---|---|---|

What % of the equipment from this measure is still in use? 0%

When was the unused portion removed from service? (approx): ______

**Why was it removed from service?**

______

**Auditors Comments:** ______

______

______

**Notes:** ______

Data Class: ______

1= Good
2= Marginal
3= Bail Out
4= Refused
5= Can't Contact
6= Duplicate

Customer Name: ____________________________________

Customer Business Name: ____________________________________

Customer Address: ____________________________________

____________________________________

Customer Phone: ____________________________________

PG&E Account Number: __________________ Verified?___________

New Account Number: __________________ (1=Yes, 2=No)

PG&E Meter Number: __________________ Verified?___________

New Meter Number: __________________ (1=Yes, 2=No)

Location/Directions (include major cross streets):

________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________

Type of Measure

| Y/N | Meas # | Measure Name |
|---|---|---|
| ______ | 1 | Pump Repair (REO) |
| ______ | 3 | Low Pressure Sprinkler Nozzle Conversion (REO) |
| ______ | 4 | Micro Irrigation System Conversion (REO) |
| ______ | 5 | Heat Curtain (REO) |
| ______ | 6 | Refrigeration (REO) |
| ______ | 7 | 1995 Retention Panel Verification |

This on-site survey conducted by: _____________________ On: ______________

Note: Verify PG&E Account Number from copy of customer's bill.

## *Pump Repair Audit* ***(page 1 of 1)***

1. Normal Pumping Plan Configuration (from pump tester's notes):

2. Was this pump worked on in: 1 = 1996 or 1997, 2 = Not worked on ____________

**<u>If Yes</u>**:

a) When was this work done (Month/Year)? <u>/</u>______

b) When work was done? _____________

(1=pump rebuilt/replaced, 2=well casing cleaned, 3=pump rebuilt & casing cleaned)

c) Was this pump re-tested after the repairs were made (1=Yes, 2=No)? _________

*If Yes*

c1) when was it re-tested _____/_____

c2) what was the plant efficiency?

3. Other electrical load on this meter? (1=Yes, 2=No, 3=Unable to determine) _____

**<u>If NO, then stop audit here; if Booster, go to #4, if OTHER, go to #5</u>**

4. *If Booster Pump*, then complete the following:

a) _____ What is the horsepower of the booster pump?

b) _____ Do the booster and deep well pump <u>always</u> run at the same time? (1=Yes, 2=No)

*If yes, then STOP here*

*If NO, then* ? (These last 3 questions should add to 100%)

i) ______ % of the time does the booster run by itself?

ii) ______ % of the time does the booster run with the deep well pump?

iii) ______ % of the time does the deep well pump run by itself

1. *If Other Loads, then what portion of the year do they run and what are their horsepowers?*

Tested Pump ______ % of year run:

Other Load #1______ % of year run and ______ Horsepower

Other Load #2______ % of year run and ______ Horsepower

Other Load #3______ % of year run and ______ Horsepower

Other Load #4______ % of year run and ______ Horsepower

## *Pump Repair Retention Panel Information*

Information for the retention portion of this audit are collected above (location of pump) and during the pump test (horsepower of pump).

Customer Contact By: ______________ On: _______ Forward To Tester On: ________

# *Pump Test Work Sheet* *(Page 1 of 2)*

## *Field Pump Test*

Location Description (major cross streets and location from intersection; include HP):

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

Normal Pumping Plant Configuration (How is it usually used):

____ Single deep well pump with open discharge

____ Single deep well pump with pressurized discharge:

____ Low (1-20 psi) or ____ High (20+ psi)

____ Single deep well pump in conjunction with electric booster pump

____ Single deep well pump in conjunction with diesel booster pump

____ Deep well joined with other deep well pumps

____ Axial / Propeller pump (low head)

____ Other: ____________________________________________________________

PG&E Meter Number (in program yr) _____________________ Verified? __________

New Meter Number (if changed)__________________________ (1-Yes, 0=No)

Are their other electrical loads on this meter? _____ (1=Yes, 0=No)

If Yes, what is the other load: [ ] Booster, [ ] Other ________________________

Sketch of Pumping Configuration:

# *Pump Test Work Sheet* *(Page 2 of 2)*

## *Field Pump Test*

Comments (include pumping plant configurations used other than the “normal” one):

______________________________________________________________________

______________________________________________________________________

Pump Test Conducted By: _________________________ On: __________________

Pump Test Data Review By: ____________ On: __________ Data Classification: ___

## *Low Pressure Sprinkler Nozzle* ***(page 1 of 3)***

The information here, unless otherwise noted, is specific to the site audited.

1. The low pressure sprinkler nozzles were placed in a system which is a:

   1 = Permanently Installed System 2 = Hand Moved System

   Total number of rebated nozzles *throughout company* - ___________

   Total number of rebated nozzles *at this site* - ___________

2. The nozzles are used across _____ pumping accounts.

3. Is the pumping pressure reduced? (1=Yes, 2=No)

   *If yes*, how was the pressure reduced:

   ______________________________________________________________________________

   ______________________________________________________________________________

4. What was the approximate psi of the previous high pressure sprinkler system? _______

5. What is the configuration of the pumping system being tested?

   a)______Deep well pump only.

   b)_____ Deep well pump in conjunction with booster pump that boosts directly from the deep well.

   Booster pump is _______ (1=Electric, 2=Diesel)

   c)_____ Deep well pump in conjunction with booster pump with the booster pump pulling water from a reservoir or canal.

   Booster pump is _______ (1=Electric, 2=Diesel)

   d)_____ No deep well pump. Electric booster used to pull water from canal.

6. *If booster pump used*, what is the current horsepower? _____

7. *If booster pump was changed* with addition of low-pressure sprinkler nozzles, what was the horsepower of the old booster pump? _____

## ***Low Pressure Sprinkler Nozzle*** ***(page 2 of 3)***

8. *If moveable sprinkler system*, complete the following information for the pumps to which the irrigation system is attached. The assumption is that all rebated nozzles are on this system. If not, make a note of where they all are. Circle the pump number of the pump that has been tested.

| Pump Number | Account Number | Pump Type (Booster, Deep Well, Combined) | Pump HP | Acres Irrigated with Pump | % of time Pump Used (column adds to 100%) |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| Total | NA | NA | NA | | 100 |

1. *If permanent sprinkler system*, complete the following information for the pumps to which the irrigation system is attached. The assumption is that the grower spread out the rebated number of nozzles across more than one account. Circle the pump number for the pump that has been tested.

| Pump Number | Account Number | Pump Type (Booster, Deep Well, Combined) | Pump HP | Number of Nozzles on Pump System | Acres Irrigated with Pump |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| Total | NA | NA | NA | | |

# *Low Pressure Sprinkler Nozzle* ***(page 3 of 3)***

## *Low Pressure Sprinkler Retention Panel Information*

Sprinkler Brand: ______________________________________

Sprinkler Model: ______________________________________

Nozzle Manufacturer: ______________________________________

Nozzle Size: ______________________________________(Inches or Model Number)

Note: Other retention information is gathered earlier (location of fields, number of nozzles, type of irrigation system).

## *Micro Irrigation Conversion* *(page 1 of 2)*

1. What was the previous irrigation system?

   ____ Big Gun sprinklers of approximately _____ psi

   ____ High Pressure sprinklers of approximately ___ psi

   ____ Low Pressure sprinklers of approximately ___ psi

   ____ Other ________________________________________________________________

2. Current estimated psi ________________

3. Current estimated irrigation efficiency ____________

4. Complete the following information for the pumps to which the irrigation system is attached. Circle the pump number for the pump that has been tested.

| Pump Number | Account Number | Pump Type (booster, deep well, both) | Pump HP | Acres Irrigated with Pump |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| Total | NA | NA | NA | |

1. At the time of the conversion to a micro system, was:

   a) _____ the deep well replaced or rebuilt (1=Yes, 2=No)?

   b) _____ the booster replaced or rebuilt (1=Yes, 2=No)?

1. If new pump, what was the old pump:

   a) _____ Type b) _____ horsepower

2. *If retrofit*, what was done to the pump? ________________________________

3. Micro-Irrigation Schedule

   Does the system have a peak-period lock-out on the meter? ________ (1=Yes, 2=No)

*Continue if #8 answer is No*

When the system is turned on, how many hours per day does it run (on average)? ___________

When are those hours? ____________________________________________________________

# *Micro Irrigation Conversion (page 2 of 2)*

## *Micro-Irrigation Retention Panel Information*

Type of micro irrigation system (e.g., drip tape, drip tubing, micro sprinklers)

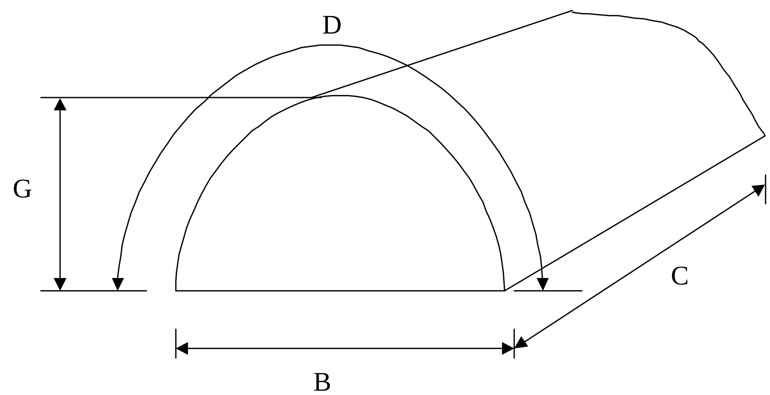
______________________________________________________________________________

______________________________________________________________________________

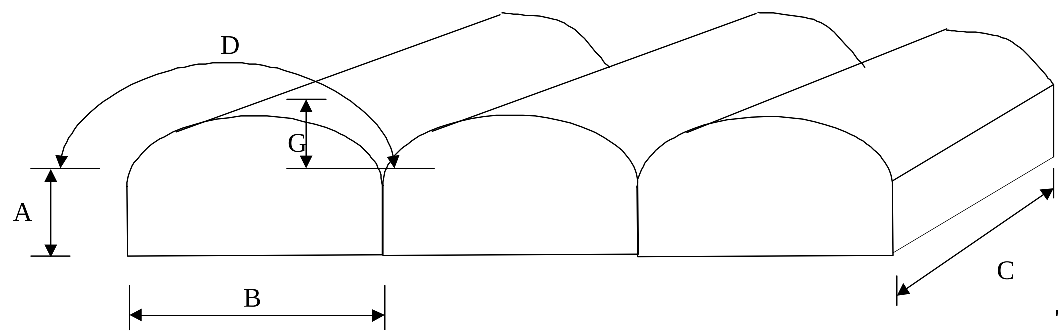
## *Greenhouse Heat Curtain* *(page 1 of 5)*

**Greenhouse Volume**

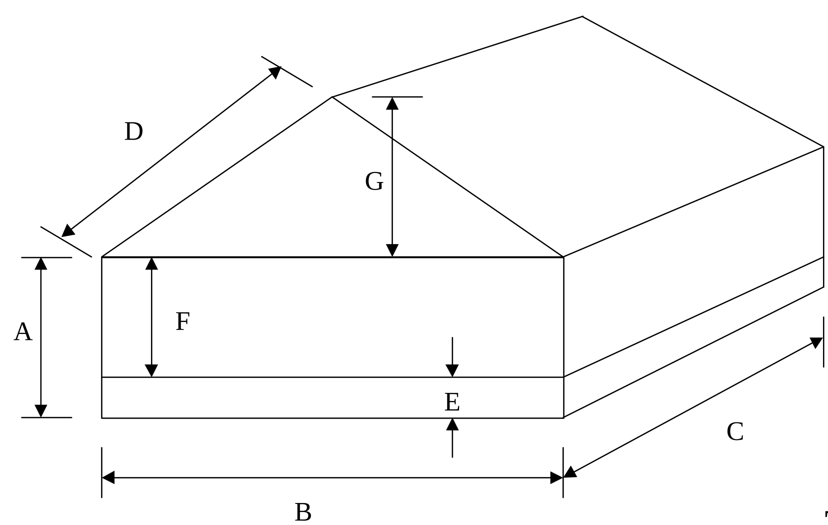
If the greenhouse being audited does not have one of the shapes shown below, draw it on the next page and label the lengths provided. Draw how the heat curtain has been installed. Measure dimensions in feet and include on Page 3.




**Type: Quonset (Q)**




**Type: Multi-Span (M)**




**Type: Rectangular (R)**

# *Greenhouse Heat Curtain* ***(page 2 of 5)***

**<u>Greenhouse Volume (cont.)</u>**

Sketch of Other Type (if required):

# ***Greenhouse Heat Curtain*** ***(page 3 of 5)***

| Greenhouse #___ | | | | | |
|---|---|---|---|---|---|
| Number the Same = | | | | | |
| GreenhouseType (Q,M,R,O) = | | | | | |
| | Meas. | Material | Heat Curtain* | | |
| Location | Feet | Type | Length AND | Width OR | Area |
| A Wall height | | | | | |
| B House Width | | | | | |
| C House Length | | | | | |
| D Rafter Length | | | | | |
| E Lower Wall Height | | | | | |
| F Upper Wall Height | | | | | |
| G Gable Height | | | | | |

Greenhouse #___

Heating Thermostat Setpoint: ______

Heating Schedule: (Months heating available and hours used if programmable thermostat)___

________________________________________

________________________________________

________________________________________

________________________________________

________________________________________

________________________________________

Comments: ______________________________

________________________________________

________________________________________

________________________________________

________________________________________

________________________________________

*If there are more than one greenhouse the same, the heat curtain is assumed to be the same in each greenhouse.

**Cloth Type:** LS14 LS15 LS15F LS16 PH1 PH98 Other
(Circle One or More)

Other:________________________________________________________________________

**Circle the type of framing materials in the greenhouse:**

Wood Aluminum Galvanized Steel

Other: ________________________________________________________________________

**Circle the Construction Age:** New Construction (less than 5 years) Old Construction (>=5 years)

**Circle the Maintenance:** Good Maintenance Poor Maintenance

# *Greenhouse Heat Curtain* *(page 4 of 5)*

## Greenhouse Construction

Use the Material Number to indicate Material Type on Page 3.

| Material Number | ***General Material Type*** | ***Typical Trade Name*** |
|---|---|---|
| 1 | Glass | Double Strength<br>Insulated Units<br>Low Iron |
| 2 | Acrylic | Plexiglass<br>Lucite<br>Acrylite<br>Double Wall Exolite Acrylite SDP |
| 3 | Polycarbonate | Lexan<br>Tuffak A<br>Tuffack Twinwall<br>Qualex |
| 4 | Fiber Reinforced Polyester | Lascolite<br>Filon<br>Glasteel<br>Kalwall |
| 5 | Laminated Acrylic/Polyester Film | Flexigard |
| 6 | Polyethylene Film | Visqueen<br>Tufflite II<br>Monsanto 602 or 603 |
| 7 | Weatherable Polyester Film | Llumar<br>Mylar<br>Melinex |

If the glazing construction material is not on this list, number it, state below what it is and refer to it as that number on page 3.

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

## *Greenhouse Heat Curtain (page 5 of 5)*

Comments on Greenhouse Audit not covered elsewhere.

## *1995 Ag Program Retention Questionnaire*

| | | |
|---|---|---|
| Customer Name | | Audit Num: |
| Business Name | | Orig CCS Surveyor |
| Customers Address | | Division |
| City | | Assigned To: |
| Phone | | Old Audit ID: |
| New Contact Name | | Date Customer Talked To: |
| New Phone Number | Area Code | Is a Site Visit Necessary? |
| PG&E Audit Acct. | | Date Site Visited |
| New PGE Acct. | | |
| 1995 Measure: | Measure Code | Measure Description |

Custom Audit
Pump Audit
Lighting Audit

Location Description – Custom, Pump Repair | Location Description – Lighting

Is the 1995 measure still present (yes/no) ____________

If not present, explain why not

___

Was the measure used in 1998?

If no, explain why not

___

Approximate date removed from service ___________________________

*Continue for Lighting Audits ONLY*

| **Num Fixtures** | **Group Descriptions** | **Lamp Fixture** | **Watt** |
|---|---|---|---|

What % of the equipment from this measure is still in use? ________________

When was the unused portion removed from service? (approx.) ________________

**Why was it removed from service?**

___

___

**Auditors Comments:**

___

___

## *Refrigeration Audit* ***(page 1 of 5)***

Measure Rebated (circle one):

1. Oversized Evaporative Condenser – Halocarbon Refrigerant
2. Oversized Evaporative Condenser – Ammonia Refrigerant
3. Non-electric Refrigerant Condensate Evaporator
4. Strip Curtains

### *If Measure is #1 or #2 – GO TO NEXT PAGE*

### *For Measure #3*

Location of Measure: ____________________________________________

____________________________________________

____________________________________________

Manufacturer: ____________________________________________

Make and Model Number: ____________________________________________

Number of Measures: ____________________

### *For Measure #4*

Location of Measure: ____________________________________________

____________________________________________

____________________________________________

Square Foot of Measure Installed: _________

Door Measurements: _________Ft. by __________ Ft.

Volume of Walk-In: __________ Ft. by ___________ Ft. by ___________ Ft.

Average Indoor Temperature ______________F

Type of HVAC System: ______________________ EER of HVAC System: ________________

Hours per Year in Use: _______________________

Schedule: ____________________________________________

____________________________________________

On-Site Audit Number: _____________
Auditor: ________________________

**Refrigerant:** Ammonia (R717)  Halocarbon (R22)

| Refrigeration | Compressors* | | | | | |
|---|---|---|---|---|---|---|
| Line | Manuf. | Model | hp | Suction Temp (F) | Pressure | |
| | | | | | | psia psig |
| | | | | | | psia psig |
| | | | | | | psia psig |
| | | | | | | psia psig |
| | | | | | | psia psig |
| | | | | | | psia psig |
| | | | | | | psia psig |

*Obtain the average compressors and cylinders running during off-peak and on-peak periods

**Refrigeration Components**

Total Refrigeration ________ Btuh  Tons  Lbs.
Flow ________ lb/min

| | Maximum | Average |
|---|---|---|
| Pre-Retrofit Suction Pressure or Temperature | | |
| Pre-Retrofit Condensing Pressure or Temperature | | |
| Post-Retrofit Suction Pressure or Temperature | | |
| Post-Retrofit Condensing Pressure or Temperature | | |

On-Site Audit Number: _____________
Auditor: ________________________

| | Condensers | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Number | Manuf. | Model | Condesing Temp (F) | Pressure | | Number of Fans | Fan hp | Number of Pumps | Pump hp |
| 1 | | | | | psia psig | | | | |
| 2 | | | | | psia psig | | | | |
| 3 | | | | | psia psig | | | | |
| 4 | | | | | psia psig | | | | |
| 5 | | | | | psia psig | | | | |
| 6 | | | | | psia psig | | | | |
| 7 | | | | | psia psig | | | | |

Location of Condenser ______________________________

______________________________

Fan Control Schedule ______________________________

______________________________

Refrigeration On-Site Audit

On-Site Audit Number: _____________
Auditor: ________________________

Line Drawing of Refrigeration Line Layout

Refrigeration On-Site Audit

On-Site Audit Number: _____________
Auditor: ________________________

Operating Hour Schedule for Plant

Gather information on seasonal, weekly hours of operation and coincident peak periods - use July and August 3-4PM as CP

# Appendix C
# Costing Period Allocation Tables

## Gross Demand and Energy Savings by Costing Period For the AEEI Program – Pumping and Related End Use

| | Pumping and Related End Use | | | |
|---|---|---|---|---|
| **PG&E Cost Period** | **Program kW Savings Coincident with System Max in Period** | **kW H-Factor** | **kWh Savings** | **kWh H-Factor** |
| Summer On-Peak:<br>May 1 to Oct 31<br>12:00 - 6:00 PM<br>Weekdays | 1,451.03916 | 1.00000 | 792,557.13094 | 0.13356 |
| Summer Partial-Peak:<br>May 1 to Oct 31<br>8:30 AM - 12:00 PM<br>6:00 PM - 9:30 PM<br>Weekdays | 1,476.44685 | 1.01751 | 957,465.50671 | 0.16135 |
| Summer Off-Peak:<br>May 1 to Oct 31<br>Other | 1,729.39200 | 1.19183 | 2,622,927.35434 | 0.44201 |
| Winter Partial-Peak:<br>Nov 1 to April 31<br>8:30 AM - 9:30 PM<br>Weekdays | 576.84611 | 0.39754 | 658,624.70772 | 0.11099 |
| Winter Off-Peak:<br>Nov 1 to April 31<br>Other | 337.38111 | 0.23251 | 902,456.48752 | 0.15208 |

The AEEI Pumping and Related End Use H-factors referenced above are from the evaluation of PG&E’s 1996 Agricultural Programs reported in March of 1998.

## Gross Demand and Energy Savings by Costing Period For the AEEI Program – Refrigeration End Use

| | Refrigeration End Use | | | |
|---|---|---|---|---|
| **PG&E Cost Period** | **Program kW Savings Coincident with System Max in Period** | **kW H-Factor** | **kWh Savings** | **kWh H-Factor** |
| Summer On-Peak: May 1 to Oct 31 12:00 - 6:00 PM Weekdays | 285.26563 | 1.00000 | 375,350.14672 | 0.14720 |
| Summer Partial-Peak: May 1 to Oct 31 8:30 AM - 12:00 PM 6:00 PM - 9:30 PM | 266.24412 | 0.93332 | 407,530.30196 | 0.15982 |
| Summer Off-Peak: May 1 to Oct 31 Other | 247.98997 | 0.86933 | 937,406.39224 | 0.36762 |
| Winter Partial-Peak: Nov 1 to April 31 8:30 AM - 9:30 PM Weekdays | 114.83083 | 0.40254 | 404,521.38095 | 0.15864 |
| Winter Off-Peak: Nov 1 to April 31 Other | 134.07770 | 0.47001 | 425,099.34076 | 0.16671 |

The AEEI Refrigeration End Use H-factors referenced above are from the evaluation of PG&E's 1996 Agricultural Programs reported in March of 1998. The indoor lighting end use H-factors used in the 1996 programs evaluation are actually H-factors for the "Ag Other" segment. Therefore, the use of these H-factors for the refrigeration end use is appropriate for the 1997 Agricultural Programs evaluation.