Impact Evaluation of the 2002 California Low Income Energy Efficiency Program

Final Report

Submitted to

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Executive Summary

This report comprises an impact evaluation of the California Low Income Energy Efficiency Program (LIEE) for program year 2002 (PY02). It was commissioned by the four participating utilities, Southern California Edison (SCE), Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E) and Southern California Gas (SoCalGas), as required by the California Public Utilities Commission (CPUC) in Decision 03-10-041, dated October 16, 2003. The study team, led by West Hill Energy & Computing, includes the Energy Center of Wisconsin, Ridge and Associates, Wirtshafter Associates, and Business and Economic Analysis, referred to collectively as the "West Hill Energy Team."

E.1 Objectives and Approach

This study was commissioned to meet three main objectives:

1) to investigate methods to estimate savings relating to the energy education component of the program
2) to review impact evaluation strategies and approaches for estimating measure-level savings in the context of the LIEE program
3) to estimate impacts of the LIEE program during program year 2002

The first component of the evaluation consists of a literature review to identify the strategies used for estimating savings impacts from energy education, presented in Chapter 3.

The second goal is addressed through a review of the California Evaluation Frameworks and other resources, culminating in the discussion of applicable methods for assessing the impacts of the LIEE program presented in Chapter 5. This information is supplemented by the detailed discussion of the issues and approaches to estimating savings at the measure level provided in Chapter 8.

The third objective was to conduct an impact evaluation of the LIEE program for the 2002 program year. This part of the study was conducted using a regression-based billing analysis, supplemented with savings estimates from external sources as needed, and is described in Chapters 4, 6 and 7.

E.2 Overview of Methods

Three strategies for future impact evaluations of the LIEE program were considered:

1) billing analysis
2) engineering and monitoring approaches
3) deemed savings

While billing analysis can be conducted after the fact and can be relatively inexpensive in comparison to other approaches, it will not necessarily provide reliable estimates of measure-level savings, especially for smaller measures frequently installed in tandem with other measures. Due to the program structure and lack of detailed pre-installation data, engineering and monitoring strategies will require a long lead time and are likely to be more expensive, although a targeted strategy could be used to limit the scope of the study. Using deemed savings is by far the least expensive option, but does not necessarily reflect the particular features of the LIEE participant base.

Given the lack of pre-installation baseline data and the timeframe and budget for this project, we concluded that a regression-based billing analysis was the only viable option for assessing the first year savings impacts for program year 2002. A review of external studies was conducted to provide a framework for assessing the validity of the regression results.

E.3 Energy Education Literature Review

From the review of other studies designed to estimate the savings from energy education, we concluded that the most reliable method to quantify these savings is to conduct a controlled experiment. Preliminary calculations suggest that a sample size of several thousand would be necessary to estimate these savings. Since the costs of such a study are likely to be prohibitive, we recommend that the LIEE rely on more qualitative approaches to assessing whether the energy education component is effective. These techniques will not be sufficient to support a specific savings estimate for energy education.

E.4 Summary of Results

The results of the analysis are discussed below, on the program and household level and then by measure category. For each category, we discuss the reliability of the regression-based estimates. Two criteria are used to establish the validity of the results:

1. whether the results are within the typical range for the measure in comparison to other studies and sources of deemed savings, such as the 2001 DEER report,
2. the statistical properties of the regression estimator

Total program savings for PY2002 (program year 2002) came to about 41,900 MWh per year and 986,900 therms per year as shown in Table E-1.

Table E-1: PY 2002 Total Program Savings

	# of Participants	Annual MWh	Annual Therms
PG&E	70,683	28,212	606,592
SCE	29,685	8,495	
SDG&E	14,089	5,216	57,576
SoCalGas	39,464		322,721
Totals		41,923	986,899

Table E-2 presents the household savings in comparison to average 2002 consumption for the current and previous two evaluations.

Table E-2: Summary of Household Savings, PY00 through PY02

	Average Annual Energy Consumption[1]	PY 2002 Evaluation	PY 2001 Evaluation	PY 2000 Evaluation
Electric Savings (kWh)				
Combined Utilities	5,070	366	213	175
PG&E	5,435	399	236	240
SCE	4,519	286	203	153
SDG&E	4,198	370	215	89
Gas Savings (Therms)				
Combined Utilities	410	8	18	24
PG&E	461	9	18	28
SDG&E	349	4	13	13
SoCalGas	386	8	20	26

The billing analysis indicates that the program is generating both electric and gas savings. On the household level, the savings account for approximately 7% of the average annual electric use and about 2% of gas use. The electric savings per household show an upward trend over the three years, which appears to be driven primarily by an accompanying increase in the penetration of efficient refrigerators. Gas savings are more variable, with particularly low savings for PY2002.

Both the gas and electric billing data showed a drop in usage during 2001, and a rebound in 2002 and 2003. The billing analysis was complicated for PY 2002 by the voluntary energy conservation efforts of California consumers during and after the California Energy Crisis, particularly affecting our ability to estimate savings for weather-dependent measures. Structural changes in the program made in 2001 and extending into 2002 may also have contributed to the difficulties in estimating program effects. In the electric model, it was not possible to estimate savings for homes with space heating and some cooling measures. The gas model showed substantially smaller savings for many space and water heating measures than found in previous years, possibly as a result of these external factors. Thus, the program savings developed from these estimates may understate the actual impacts.

In general, the regression results were reasonably precise for measures with substantial savings and a high frequency of installation, such as refrigerators. For many smaller and less frequently installed measures, the precision is low and the estimators may be less than reliable, as indicated by the wide confidence intervals and instability of estimated measure-level savings under alternative model formulations. The reasons for this are

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[1] This column reflects the average annualized kWh consumption for 2002 participants who were included in the account sample.

varied, including the following:

- small relative impacts for many measures
- uncertainty associated with the designators for water and space heating fuels, and lack of data on the presence of air conditioning and functionality of existing equipment
- sensitivity of savings estimates for some measures to outliers and influential data points
- inability to disentangle savings from measures that are typically installed together

In addition, the confidence intervals are wider than those shown in previous evaluations due to our application of alternative statistical methods to calculate intervals that more accurately reflect the variation associated with the time-series, cross-sectional regression.

Each measure category is listed below with a discussion of the results. Chapter 8 presents a detailed discussion of the specific issues related to assessing the impacts of each measure, summarized in Table 8-1.

E.4.1 Refrigerators

Refrigerator replacement has a clear, large impact on electricity use that is readily detectable in customer billing data, as indicated by the robust estimator derived from the regression analysis. Moreover, the estimated savings from refrigerator replacement have been consistent over several evaluations, and are consistent with expectations given the replacement criteria used by the program.

We feel that impacts from this measure, which represents a high proportion of the total electric savings, are reliably estimated using the current methods. Refrigerator savings were found to be in the range of 665 to 700 annual kWh.

E.4.2 Lighting

Compact fluorescent light bulbs are also an important contributor to aggregate impacts, since they are installed in a large majority of homes. Our estimates of CFL savings are relatively consistent with previous evaluations, but we also found that these savings are somewhat unstable in that the estimates vary under alternative formulations of the model. The high installation rate of the measure makes it difficult to statistically disentangle CFL savings from other almost ubiquitous program effects, such as potential impacts from energy education efforts.

Lighting savings were found to be in the range of 21 to 43 annual kWh per bulb. These savings are on the low end of the typical range of savings estimated for this measure.

E.4.3 Cooling

Savings from cooling measures are difficult to assess from the regression model. The SCE cooling model tended to provide imprecise estimators, although it clearly showed savings.[2] For PG&E, the model was stable but produced a surprisingly high estimate of savings for evaporative cooler maintenance. These results could be related to the 2001 Energy Crisis, improper use of the installed equipment, or inoperable equipment in some homes during the pre-installation period.

In comparison to other sources, the SCE savings seem to be in a normal range for evaporative cooler installation and maintenance, and somewhat low for air conditioners. PG&E's savings for evaporative cooler maintenance are much higher than would be expected but have only a small impact on total program savings due to the relatively few installations.

SCE's savings are estimated at 371 annual kWh for evaporative cooler installations, 102 for maintenance and 83 kWh for air conditioner replacements. PG&E savings for evaporative cooler maintenance are estimated to be 512 kWh per year.

E.4.4 Heating Systems

Furnace replacement and repair, programmable thermostats, and duct replacement show an increase in use in the regression model. In the gas model, a term is included for each measure and the stability of the estimators varied. This finding may be the result of many units being inoperable prior to program services. The Energy Crisis could also be a contributing factor to this result.

In the electric model, heating system and envelope measures as a group showed an increase in use in the post period, as did all homes with electric space heat. Consequently, it was not possible to develop savings estimates for these measures.

E.4.5 Attic Insulation

The savings for attic insulation are reasonably consistent with previous evaluations and the deemed savings the DEER report. PY2002 savings for single family homes are estimated at 27, 32 and 48 therms per year for SoCalGas, SDG&E and PG&E, respectively.

E.4.6 Other Space Heating Measures

A bundled term was included in the gas model to include savings from furnace filters, weatherstripping, caulking, miscellaneous home repairs, evaporative cooler covers and outlet gaskets. The aggregate savings were distributed to the measures proportionally on the basis of the DEER deemed savings.

The regression estimator is statistically significant. It shows some variability associated with influence from outliers, although the analysis of outliers suggests that the savings may be understated.

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[2] Weighting the model for outliers tended to shift savings among the three cooling measures, i.e., air-conditioner replacement, evaporative cooler installation and maintenance.

These results indicate there are small savings associated with this bundle of measures, estimated at 4, 5 and 9 therms per year for SoCalGas, SDG&E, and PG&E, respectively. The measure-level estimates are based on the relative weight of the measure from the DEER savings, and may or may not reflect the actual conditions in the LIEE homes.

E.4.7 Water Heating Conservation Measures

Water heating measures were also modeled as a package in the regression model and distributed proportionately using the DEER Report. Estimating electric domestic hot water ("DHW") savings is problematic since almost all of the homes receiving these measures also have electric space heating, causing a high degree of variability in the consumption for these homes. A similar issue arose with the gas model.

The regression term tended to be unstable, susceptible to changes in the mix of variables included in the model and, for the electric model, the exclusion of outliers. The precision is low, as reflected in the wide confidence intervals. For SDG&E, the package estimator for electric savings is not statistically significant. As with the space heating measures, the measure-level estimates are based on the DEER proportions and do not reflect the actual conditions in the homes.

Despite these caveats, the electric DHW package savings seem to be reasonably consistent with estimates from other sources for SCE and SDG&E. DHW package savings are expected to be 104, 261 and 213 kWh per year for PG&E, SCE and SDG&E, respectively.

In the gas model, the DHW package term produced unusually low savings. On average, the savings for the gas DHW package are estimated at approximately 4 therms per year. The measure-level savings are subject to the same limitations as the other bundled measures.

E.4.8 Energy Education

The regression model shows evidence of a general program effect above and beyond the measures installed. This effect could include behavioral changes resulting from the energy education component of the program. Given that efficient lighting and/or refrigerators are installed in a large majority of homes, further modeling shows it is not possible to develop estimates of the program effect that are completely independent of the savings from these base measures.

E.5 Summary of Recommendations

The recommendations are summarized in Table E-3.

Table E-3: Summary of Recommendations

Number	Topic	Description
10.1	Improve data collection	▪ Incorporate collection of additional data into regular program implementation (detailed list is provided in Table 10-2)
10.2	Set priorities for next evaluation	▪ Decide whether greater certainty on measure-level savings is necessary or household savings with adjusted deemed savings for measure-level estimates are sufficient
10.3	Establish appropriate time line	▪ If engineering and/or monitoring methods are preferred, bring in evaluators *prior* to the program year under review
10.4	Define the scope of the sample plan	▪ Select measures to be investigated ▪ Consider costs associated with each approach
10.5	Assessing savings from energy education	▪ Controlled experiment is best method for obtaining quantitative results, but likely to be cost prohibitive ▪ Consider qualitative assessment through surveys to assess whether impacts exist
10.6	Applying the results of this evaluation	▪ Measure-level estimates for most electric, non-weather sensitive measures are within a reasonable range for program planning and reporting purposes ▪ Estimates for weather sensitive measures and gas DHW conservation measures in the PY2002 should not be used for program planning ▪ PY2000 and 2001 evaluations may also suffer from some of the same shortcomings ▪ Deemed savings can be used for DHW conservation and weather-sensitive measures until better estimates are available
10.7	Postpone next evaluation until 2005	▪ The scheduled evaluation for PY2004 will be subject to many of the same problems found in the PY2002 evaluation ▪ Data collection could be modified for PY2005 and evaluation planning commence immediately to improve the results for PY2005

1 Introduction

This report comprises an impact evaluation of the California Low Income Energy Efficiency Program (LIEE) for program year 2002 (PY02). It was commissioned by the four participating utilities, Southern California Edison (SCE), Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E) and Southern California Gas (SoCalGas), as required by the California Public Utilities Commission (CPUC) in Decision 03-10-041, dated October 16, 2003. The study team, led by West Hill Energy & Computing, includes the Energy Center of Wisconsin, Ridge and Associates, Wirtshafter Associates, and Business and Economic Analysis, referred to collectively as the "West Hill Energy Team."

1.1 Overview

This study was commissioned to meet three main objectives:

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The first component of the evaluation consists of a literature review to identify the strategies used for estimating savings impacts from energy education, presented in Chapter 3.

The second goal is addressed through a review of the California Evaluation Frameworks and other resources, culminating in the discussion of applicable methods for assessing the impacts of the LIEE program presented in Chapter 5. This discussion covers the available evaluation techniques, the issues specific to the LIEE that affect the choices and trade offs between the data useful for evaluation and the costs of acquiring the data. This information is supplemented by the detailed discussion of the issues and approaches to estimating savings at the measure level provided in Chapter 8.

The third objective was to conduct an impact evaluation of the LIEE program for the 2002 program year. The utilities requested savings by utility, by house type and by measure. This part of the study was conducted using a regression-based billing analysis, supplemented with savings estimates from external sources as needed, and is described in Chapters 4, 6 and 7.

1.2 Approach to the 2002 Impact Evaluation

Initially, the West Hill Team considered a number of alternative approaches to evaluating the impacts of specific measures in this program. Ultimately, it became clear that a regression-based billing analysis was the only real alternative given the characteristics of the program, the available data, the timeframe and the budget.

Engineering and monitoring techniques were eliminated as options because they require access to detailed pre-installation data at each home. The program as implemented is designed to ensure that all *feasible* measures are installed. Consequently, the program tracking data do not include sufficient detail regarding the pre-installation conditions of the home to apply engineering methods. After-the-fact telephone surveys may not be a reliable source of detailed information as they rely on the recollection of occupants who generally lack the necessary technical expertise. Since our team was hired after the completion of the 2002 program year, the opportunity to collect additional information on the pre-installation conditions was lost.

Billing data are available after the fact and billing analysis is one commonly used approach to estimate impacts. It is most useful for estimating savings at the household level and for measures that save a substantial proportion of the total household consumption. By increasing the sample size, it is possible to obtain estimates for smaller impacts. However, there were a number of aspects of the LIEE program that made the billing analysis more complicated.

- The utilities requested measure-level savings by utility, housing type and measure. Over twenty measures were offered by the four participating utilities to low-income customers in three housing types through the LIEE program during 2002, many of which would typically be expected to result in small savings. Including many variables reflecting measures installed concurrently into the regression analysis can introduce collinearity to the model and the resulting saving estimates, especially for smaller measures, tend to be unstable and not necessarily reliable.
- The program tracking systems are not an entirely reliable source of some valuable data to inform the billing analysis, such as the fuel type for space and water heating.
- Some measures, such as furnace and evaporative cooler repair and replacement, restore functionality to an appliance that was previously inoperable, with the result that energy use increases rather than decreases following participation in the program.
- The 2001 Energy Crisis in California prompted widespread appeals for California residents to conserve energy. These appeals were apparently successful as there is documented lowered energy consumption in the period prior to the installation of program measures. Some effects may have lingered throughout the study period.
- Changes to program implementation, including the addition of a new set of measures (“rapid deployment” measures), were mandated in mid-2001 and

ramped up during late 2001, possibly into early 2002, adding another layer of uncertainty to the analysis.

One issue with previous LIEE evaluations based on billing analysis is that the results for specific measures tended to vary from one year to the next. Many of the factors listed above, in addition to year-to-year variations in housing stock and other external conditions, could contribute to this result.

Given these constraints, our approach to the billing analysis was to conduct a regression analysis, defining the measures or groups of measures that may reasonably be expected to be identified through this type of analysis, and to compare overall results to a simple pre/post analysis. When necessary, savings for bundled measures were disaggregated proportionally based on the deemed savings from the DEER report. The regression analysis did not produce reliable results by both measure and housing type, so the measure savings were distributed to housing types using external data sources and the more reliable estimates of multifamily and single family heating and cooling loads from the regression analysis. We separately modeled cooling measures for PG&E and SCE to reduce the number of factors affecting the savings estimates, and using this approach, we were able to estimate savings for some of the cooling measures.

Our team also considered conducting a telephone survey of participants. However, the large sample size for the billing analysis, i.e., all participants with sufficient billing history, reduces some of the uncertainty inherent in the billing analysis approach. The team was also concerned that telephone surveys may not be a reliable source for the topics of most interest. Asking questions about pre-installation conditions two years after the fact, particularly in the residential low income sector, may not produce reliable results and much of the data needed is technical in nature. Our team also noted that although KEMA-Xenergy conducted a telephone survey for their impact evaluation of the 2000 program year, using the data from that survey to refine the billing analysis did not improve the results of the model. Ultimately, KEMA-Xenergy decided to rely on the advantage of the large sample size over the enhanced data collected for the subset of participants who responded to the telephone survey.

1.3 Organization of the Report

The remainder of the report consists of nine sections: program description, energy education literature review, data collection and issues, approaches to impact evaluation, methods and analysis, results, measure details, discussion, and recommendations. References are included at the end of each chapter.

A brief overview of the LIEE Program is provided in Chapter 2, Program Description.

The results of our literature review of techniques to assess program savings from energy education are presented in Chapter 3.

The source of the data used, collection methods, scope of the data collected, and important data anomalies are described in Chapter 4, Data Collection and Issues.

A discussion of the available methods for impact evaluation and their application to the LIEE program are covered in Chapter 5.

The statistical and analytical methods and decisions used in completing the 2002 billing analysis can be found in Chapter 6, Methods and Analysis.

Chapter 7 presents the results of the analysis, and Chapter 8 provides a detailed discussion by measure of the issues involved in estimating impacts as well as approaches for obtaining greater certainty on measure-level savings.

The impacts of the Energy Crisis and other external factors affecting the results of the analysis are discussed in Chapter 9, and recommendations provided in Chapter 10.

2 Program Description

The LIEE program is delivered throughout the state of California by the major gas and electric utilities. The participating utilities include Pacific Gas & Electric (PG&E), Southern California Edison (SCE), San Diego Gas & Electric (SDG&E) and Southern California Gas (SCG or SoCalGas). The program is designed to help low income households conserve energy, thus lowering monthly energy costs and reducing the financial burden of energy bills. All services are provided free of charge to participating households.

2.1 Overview

Overall, the services and measures offered through the participating utilities are equivalent and consist of energy education and the installation of energy savings measures. The measures offered through the program vary somewhat depending on service territory and climate zone. The program installs energy savings measures associated with air conditioning, lighting, refrigeration, water heating and space heating.

In general, program delivery is a turnkey operation where the individual utilities subcontract out the program delivery to community based organizations (CBO’s) and local contractors within the service area. These delivery agents are responsible for income verification, in home energy education and the delivery and installation of the energy efficiency measures. Referrals are provided by the utilities or through the outreach efforts of the CBO’s and contractors. All service providers receive training through the utilities to ensure consistent service across the service territories.

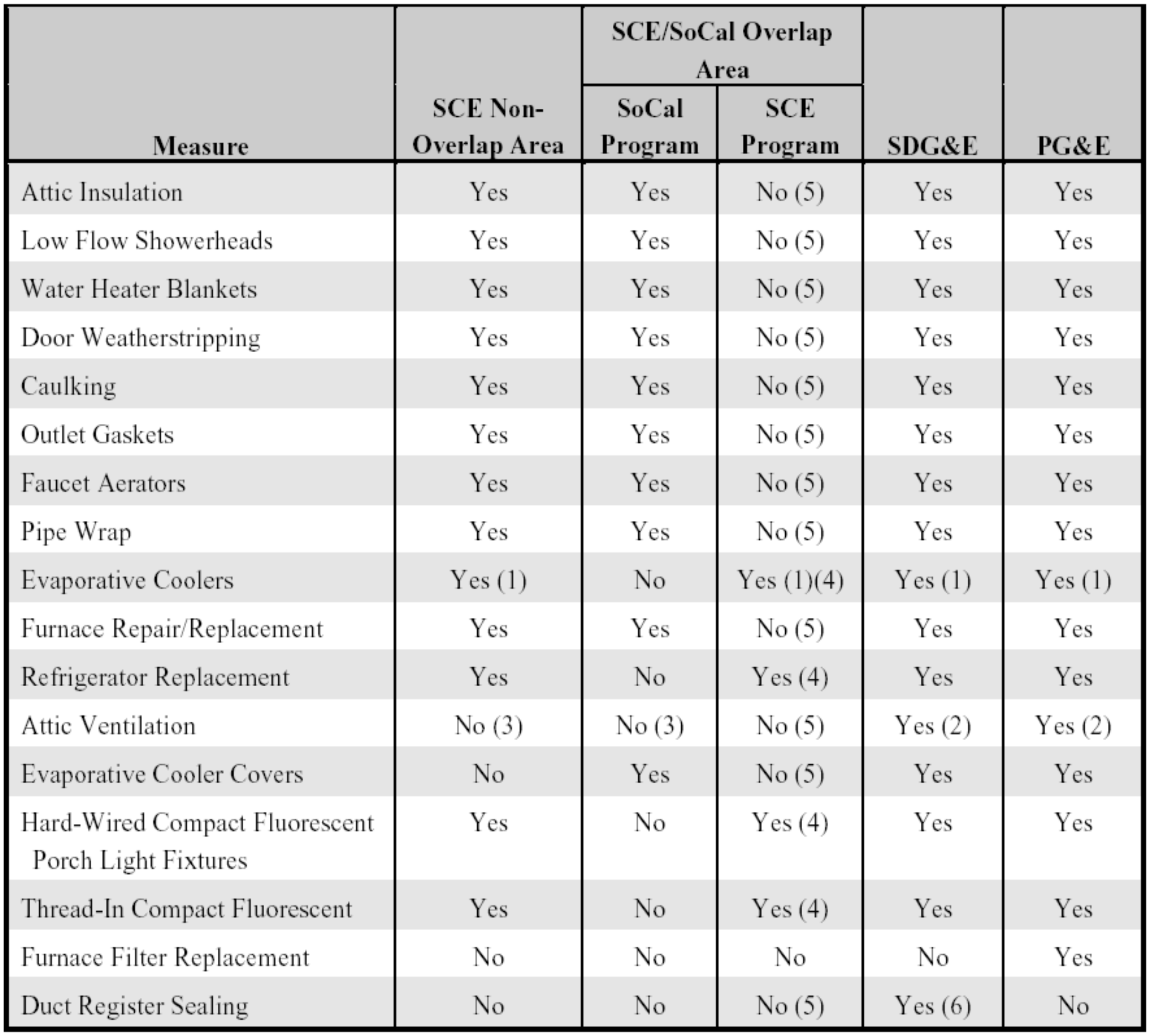
2.2 Income Eligibility

Eligibility is based on household size and income level. Income guidelines for the program are set at 175% of the federal poverty level. If the head of household is 60 years of age, older or disabled, eligibility is increased to 200% of the federal poverty guideline.

2.3 Program Measures

The goal of the program is to install all feasible energy efficiency measures in qualifying low-income households. These services are offered at no cost to participants, allowing these households to obtain the benefit of energy efficiency programs without financial constraints. Table 2-1 identifies the specific measures offered through the program as provided in the California Statewide LIEE Policy and Procedures Manual, December 2001 (P&P Manual).

Program guidelines call for the installation of all eligible measures that are feasible. In effect, no household or measure level cost-effectiveness criteria are applied on a per participant basis. Non-feasibility criteria are provided in the P&P Manual for all measures. Generally measures are considered non-feasible when they are already present, are refused by the customer, cannot be physically installed, would create a safety hazard, or violate code.



Measure	SCE Non-Overlap Area	SCE/SoCal Overlap Area SoCal Program	SCE/SoCal Overlap Area SCE Program	SDG&E	PG&E
Attic Insulation	Yes	Yes	No (5)	Yes	Yes
Low Flow Showerheads	Yes	Yes	No (5)	Yes	Yes
Water Heater Blankets	Yes	Yes	No (5)	Yes	Yes
Door Weatherstripping	Yes	Yes	No (5)	Yes	Yes
Caulking	Yes	Yes	No (5)	Yes	Yes
Outlet Gaskets	Yes	Yes	No (5)	Yes	Yes
Faucet Aerators	Yes	Yes	No (5)	Yes	Yes
Pipe Wrap	Yes	Yes	No (5)	Yes	Yes
Evaporative Coolers	Yes (1)	No	Yes (1)(4)	Yes (1)	Yes (1)
Furnace Repair/Replacement	Yes	Yes	No (5)	Yes	Yes
Refrigerator Replacement	Yes	No	Yes (4)	Yes	Yes
Attic Ventilation	No (3)	No (3)	No (5)	Yes (2)	Yes (2)
Evaporative Cooler Covers	No	Yes	No (5)	Yes	Yes
Hard-Wired Compact Fluorescent Porch Light Fixtures	Yes	No	Yes (4)	Yes	Yes
Thread-In Compact Fluorescent	Yes	No	Yes (4)	Yes	Yes
Furnace Filter Replacement	No	No	No	No	Yes
Duct Register Sealing	No	No	No (5)	Yes (6)	No

Table 2-1: Eligible Measures for PY 2002[3]

Notes to Table 2-1:
(1) PG&E offers a portable evaporative cooler, while the other electric utilities offer a window/wall unit.
(2) Offered in conjunction with attic insulation, and as a measure on a pilot basis, per E-3586.
(3) Offered only in conjunction with attic insulation.
(4) Not offered by SoCalGas, but offered by SCE outside the jointly administered SoCalGas/SCE program.
(5) Offered to SCE customers by SoCalGas under joint utility agreement.

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[3] *2001 Statewide P&P Manual*, p. 5-2.

(6) Mobile homes only

Beginning in PY 2001 the program also began offering "rapid deployment measures" in response to the "California Energy Crisis."[4] In Appendix B of the P&P Manual, the additional measures associated with the rapid deployment initiative are described as follows:

- high efficiency window/wall air conditioners
- high efficiency central air conditioners
- high efficiency gas water heaters
- high efficiency electric water heaters
- programmable and setback thermostats
- duct repair and sealing
- whole-house fans, and
- evaporative cooler maintenance

When necessary to complete the installation of eligible measures, contractors are also allowed to provide minor home repairs. The P&P Manual provides per household and program budget limits for these activities.

2.4 Other Services Provided by the LIEE

In addition to "hardware" measures such as replacement refrigerators, light bulbs and insulation, the LIEE program also encompasses an in-home energy education component. As defined in the P&P Manual, the energy education component must include information for participants on the following topics:

- general levels of usage associated with specific end uses and appliances
- the impacts on usage of measures offered through the program
- practices (and the costs of those practices) that diminish savings from the measures installed under the program
- ways to decrease usage through changes in practices
- information about other related programs (such as CARE)
- appliance safety information
- how to read the utility bill, and
- procedures used to test gas appliances

All four utilities provide educational materials to participants on the above topics, and have a protocol that calls for reviewing this literature with the client. Some utilities conduct a walk-through with the participant, and focus the discussion on opportunities for savings energy that are applicable to the specific home.

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[4] See for example, CPUC Decision D.01-05-033.

3 Energy Education Literature Review

3.1 Overview

The participating utilities requested that we investigate the "feasibility of developing specific savings estimates for energy education in our billing analysis.…"[5] This task was accomplished through a literature review to assess the techniques employed to quantify the impacts of energy education. Given this objective, the review was primarily focused on assessing 1) programs with energy education components that are similar to the LIEE program and 2) methods designed to quantify the *energy* impacts of energy education.

As discussed in Chapter 2, Section 2.4, all of the utilities provide energy education as part of the LIEE Program. Methods to achieve these goals vary by utility. We reviewed the client materials used for energy education, and also conducted brief interviews with utility staff familiar with the program to get a sense of the protocols for implementing the in-home energy education.

While there are many strategies for evaluating energy education, obtaining solid estimates of impacts to incorporate into program savings requires a high degree of rigor. Our findings indicate the most commonly employed method that meets this standard is a controlled experiment with a two-group design, i.e., a simple comparison of usage before and after the delivery of energy education, with savings for energy education recipients contrasted against those for similar households that did not receive energy education.

We discuss the results of a number of these studies below. They provide us with a range of approaches and results that may inform future LIEE evaluation activities. However, given the differences in program design, housing stock and climate, it is not appropriate to consider the results of any of these other studies to be directly applicable to the LIEE program. Rather, developing savings estimates from participant education will require a plan specifically targeted to assessing the energy education component of the LIEE program.

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[5] Request for Proposals, issued by SCE in November, 2003, page 2.

3.2 Scope of Literature Review

The term “energy education” takes on different meanings in different contexts: from efforts to increase awareness and understanding of energy issues in school settings; to mass-media campaigns intended to change behavior; to intensive client counseling that may involve incentives for subsequent reductions in energy usage. However, we limited our review to literature that was most comparable with the LIEE program efforts; namely, evaluations of programs that involved in-home counseling on energy use and energy savings tips in conjunction with the installation of traditional home weatherization measures.

We also limited the literature review to the *energy* impacts associated with energy education. Thus, while the required elements of the LIEE energy education component also include cross-referral to other programs, appliance safety, and efforts to improve understanding of the utility bill, our review was focused on the aspects intended to reduce gas and electric usage via in-home education.

Our review included searching the following sources for related literature:

- Literature archived on the CALMAC site
- Literature in the Evaluation and Market Research database maintained by the Consortium for Energy Efficiency
- Past proceedings from the American Council for an Energy Efficient Economy Summer Studies
- Past proceedings from the International Energy Program Evaluation Conference
- Back issues of *Home Energy* magazine
- Literature at the Energy Center of Wisconsin library

The literature review and discussion that follows also encompasses the recently released draft California Evaluation Framework (TecMarket Works, 2004).

3.3 Findings

Our review turned up about a dozen publications and articles of high relevance to the LIEE program. Two of these (Quaid 1990 and Green and Skumatz 2000) are themselves reviews of the energy education literature, and reference additional studies that we were otherwise unable to obtain directly. Most of the relevant literature dates from the late 1980s and early 1990s, and is attributable to a handful of authors who were active in assessing and promoting energy education for low-income programs at the time.

Overall, the literature show that a single method for evaluating the energy impacts of in-home energy education is overwhelmingly prevalent, i.e., a simple comparison of usage before and after the delivery of energy education, with savings for energy education recipients contrasted against those for similar households that did not receive energy education. The purpose of the latter group is to net out factors other than energy education that might influence savings—most notably other measures installed by the program for which energy education is being evaluated. This classic design, which Cook and Campbell (1979) term a two-group, pretest-posttest design, is discussed in the draft California Evaluation Framework under the section titled “The Billing Analysis Path” and is also specifically identified as a method for evaluating informational and energy education programs in the “Information/Educational Program Evaluations” section. Other aspects of the latter chapter may also be useful for refining the overall evaluation strategy for the educational component of the LIEE program, such as establishing clear, measurable goals and relying on process evaluation to assess the effectiveness of the implementation.

Below we briefly describe some of the more widely cited studies to illustrate actual applications of the two-group approach in the context of measuring the impacts of energy education. The two-group approach is an effective method of quantifying the impacts of energy education, regardless of the specific features of the energy education component or other aspects of program delivery. (Additional studies are included in the references.) While we have summarized results from these studies as well, it should be noted that the implementation of energy education in these programs may be very different from that of the LIEE program, and consequently savings from the LIEE energy education component may not conform to the results cited here. The purpose of presenting some of the results of these studies is to provide context and a possible range of savings associated with the energy education in low-income, audit-driven programs.

3.3.1 Penelec field test by the Alliance to Save Energy

In 1991, the Alliance to Save Energy conducted a field test designed to elucidate the electricity savings attributable to energy education for low-income customers of Pennsylvania Electric Company with electric water heaters and non-electric space heat (Harrigan, 1991). Four experimental groups were formed for the study: (1) customers who received only water heater weatherization measures (control group), (2) customers who received the water heater measures and viewed a short video developed for the program, (3) customers who received the measures, viewed the video, and also participated in a single in-home education session; and, (4) customers who received the measures, viewed the video and participated in three in-home sessions. Customers in all groups were switched to time-of-day rates; thus, some part of the energy education effort was probably directed toward shifting usage to off-peak hours rather than conserving energy. The study group sizes were small, ranging from 19 to 25 per group.

Analysis of 8- to 14-months of pre- and post-treatment electricity usage data showed 8 percent savings for the control group, and 10 to 16 percent savings for the three experimental groups, with higher savings associated with increasing level of intervention. Despite the small sample sizes, the difference in savings between the group with the highest savings and the comparison group (8 percentage points) was found to be statistically significant at a 90% confidence level.

3.3.2 Niagra Mohawk Persistence Study

A 1992 study by the Alliance to Save Energy and a 1994 follow-up study (Harrigan and Gregory, 1992 and 1994) looked at the savings—and persistence of savings—for payment-troubled low-income customers of Niagra Mohawk in upstate New York. The studies focused on natural gas savings for a group of customers who received a package of weatherization measures plus a setback thermostat and energy education, compared to a comparison group of customers who received the weatherization measures but not the thermostat or the energy education. The education component consisted of three in-home education sessions, two of which focused on energy use and ways to save energy (the third focused on payment issues). Follow-up letters were included in subsequent bills to provide feedback on changes in energy use, and customers were guaranteed that their service would not be disconnected so long as they made a mutually agreed upon payment each month.

The results (Harrigan and Gregory, 1994) showed 24 percent savings in the first year for the weatherization-plus-education group (n=71) compared to 14 percent for the weatherization-only group. Third-year savings declined slightly for both groups (20% and 13%, respectively), but the difference between the two groups remained substantial and statistically significant.

3.3.3 Michigan Study

A 1989 study (Witte and Kushler, 1989) looked at the incremental savings from adding education and financial incentives to a package of low-income weatherization measures offered by the Michigan Consolidated Gas Company. Two hundred thirty one program participants were randomly assigned to either receive or not receive an education and incentives package that included distribution of low-cost measures, on-site information on behaviors to save energy, financial incentives for achieving reductions in gas use, and feedback on changes in consumption. Preliminary results for the first January following implementation indicated 24.5 percent savings for the experimental treatment group compared to 16.4 percent for the control group that received only weatherization measures. The difference between the two groups was found to be statistically significant at a 95 percent confidence level.

3.3.4 Ohio Study

The Ohio Department of Development implemented a pilot study of client education in 1986 through 1988 (Gregory and Williams, 1989, in Quaid 1990a, 1990b). Clients in the education group received an initial one-hour home visit, during which an energy-saving action play was developed. Clients also received written materials and a two-year “conservation” calendar. In the majority of cases a second home visit was made to determine if the client had followed the action plan. Analysis of pre/post treatment bills for these households showed an average of 20 percent savings, compared to 16 percent for a control group of households that did not receive the education package.

3.3.5 Cinergy Study

In 1997 and 1998, Cinergy implemented a pilot education program with 100 low-income customers in its Cincinnati Gas & Electric Service territory (Morgan et al., 1999). Participants in the pilot effort (whose homes had previously been weatherized by the utility) received four in-home educational sessions, budget counseling, and a home energy audit. Participants received financial incentives (in the form of bill credits and arrearage forgiveness) for participating in the educational sessions and reducing energy use. These activities clearly go far beyond the level of energy education currently offered through the LIEE program

The evaluation of the pilot conducted by TecMarket Works included both process and impact components. The process evaluation relied on interviews with staff and clients. The impact evaluation examined changes in usage between the year prior to participation and the six months following participation for 94 participant households and a matched group of 164 households that were eligible for the program. The results suggested a 2 to 3 percent annual reduction in usage due to participation in the pilot.[6]

Green and Skumatz (2000) and Quaid (1990a, 1990b) summarize these (except the Cinergy Study) and other studies, and conclude that the incremental savings from adding an education component to a low-income weatherization program can range from negligible to as much as 15 percentage points. It is not possible to determine where the LIEE program would fall in this range.

3.4 Methodological Issues

Though one classic design for assessing the impacts of energy education appears to be ubiquitous, the literature varies somewhat in how the design is executed. We turn next to some of these issues and their implications for evaluating the energy education component in the LIEE program.

3.4.1 Equivalence of groups

The single most important assumption with the pre/post, treatment/control design is that the two groups are equivalent in every way except for the fact that the former receives energy education while the latter does not. If this is not true, then differences in energy savings from factors other than the education component itself will be falsely attributed to the energy education and the estimate of savings from energy education will be biased.

The gold-standard for achieving equivalence between the treatment and control groups is random assignment. If the sample size is sufficiently large to account for potential differences among service territories and contractors, and households are randomly assigned to either receive or not receive energy education, then one can be assured that the only factor that differs systematically between the two groups is the energy education, and the difference in savings between the two groups is an unbiased estimate of the energy education effect on usage. Only one study that we reviewed (the Michigan study) specifically noted random assignment as part of the evaluation design.

More common was the use of matched comparison groups drawn from the same eligible population as the households that received energy education—but without random

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[6] A similar approach was used to evaluate a non low-income residential audit program by Cinergy at about the same time. See Riggert, *et. al.*, 1999.

assignment.[7] These *observational* studies (as opposed to *experimental* designs that use random assignment) have a higher burden to document that there are no systematic differences between the two groups other than the energy education. A number of the studies we reviewed took pains to document the equivalence of treatment and control groups in terms of demographics, home characteristics and pre-participation energy use (although some did not even provide this basic information).

A notable omission from most of the studies, however, is an examination of the incidence of weatherization measures that are typically installed around the same time that energy education is delivered. Even small differences in installation rates for high-impact measures could adversely affect the estimate of energy education savings. For example if the savings from refrigerator replacement are on the order of 600 kWh/year and 50 percent of energy education group clients receive a new refrigerator compared to only 45 percent of the control group, the simple difference in the incidence rate will create a 30 kWh/year overestimate in the annual electricity savings from energy education. Moreover, since some education is specifically targeted at maintenance of the measures that were installed, it is important to document that these measures are installed with the same frequency in the two groups.[8]

The lesson is clear: the use of matched comparison groups requires careful analysis of potential sources of bias due to non-equivalence between the two groups. Moreover, the smaller the impact being measured, the more important these potential biases become.

However, while random assignment offers significant theoretical advantages, it poses logistical and—to some—ethical hurdles. As noted in the California Evaluation Framework, some have argued that publicly offered programs cannot—for political and even legal reasons—withhold treatment, even for evaluative purposes. This could be especially challenging for the LIEE program, where energy education is already a standard program component. In contrast, all of the studies we reviewed involved pilot efforts to test the application of energy education to programs that did not already offer this element.

The Framework document does provide suggestions for ways around this difficulty, however, including simply delaying for a certain period the delivery of energy education.

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[7] It is conventional among many evaluators to use the term “control group” only when random assignment occurs in a true experimental context, and use “comparison group” in other circumstances. See TecMarket Works, 2004.

[8] On a related note, some of the studies we reviewed mis-applied formal statistical tests to establish equivalence between the two groups. These studies (e.g., Witte and Kushler) looked for statistically significant differences across the groups on various parameters, and finding none, presumed the two groups were equivalent. However, statistical tests are designed to be conservative, and lack of a statistically significant difference does not establish that two groups are in fact equivalent (it may just mean that the data are inconclusive). A better approach is to presume a difference, and use the point estimates of differences in individual parameters to examine the probable impact on the results. If these bias estimates are small in relation to the sampling uncertainty, then they are unlikely to be of concern. Cochran (1983) discusses these issues in more detail.

Withholding energy education for a random set of clients also poses logistical hurdles, though not insurmountable ones. A workable procedure for field staff to randomly select control group homes would need to be developed, the materials left with the client modified, and a record of these homes kept. Given these logistical issues, it might be desirable to limit any such study to selected implementation agencies, though of course this must be weighed against the ability to generalize the results.

3.4.2 Sample size and statistical resolution

For the most part, sample sizes for the studies we reviewed were small, rarely exceeding 100 households in each group. Smaller samples sizes mean greater statistical uncertainty in the results. Though several studies reported that the difference in savings between the education group and the control group was statistically significant (i.e., unlikely to be zero for the larger population), most did not provide confidence intervals on the incremental savings from the energy education component. For one report that provided sufficient summary information to allow these calculations (Harrigan and Gregory, 1994), the uncertainty on the estimated 14 percentage point incremental savings from education is about 6 percentage points at a 90% confidence level or in other words, there is 40 percent uncertainty in the magnitude of the energy education savings.

To be sure, the goal of most of these studies appears to be more about establishing that there is *some* impact from energy education rather than precisely measuring the magnitude of those impacts. However, in the context of the desire to increase the precision of the measure-level savings estimates for the LIEE program, achieving good statistical precision takes on more importance.

Fortunately, past and current impact evaluations can provide the necessary data to permit up-front analysis to establish the statistical uncertainty associated with any contemplated design or study group size. In fact, the models developed for our assessment of the PY2002 impacts provide some sense of likely range of impacts from energy education, and the size of study groups required to obtain reasonably reliable and precise estimates of those impacts in the future.

Estimates of savings not attributable to other modeled measures were developed from the regression analyses, as described in more detail in Chapter 6.6 and Appendix A-2. In theory, these estimates reflect any savings attributable to energy education, plus any savings for measures not otherwise accounted for in other terms in the model. (Nearly all measures were included). In practice, however, the fact that most participants also receive light bulbs means that some lighting impacts may also be included in these estimates due to collinearity issues that we discuss later in this report. The confounding effect of the California energy crisis also somewhat clouds the ability to disaggregate energy education.

Nonetheless, if we assume that these estimates represent an approximate *upper limit* on the average savings from energy education, then the results suggest energy education impacts on the order of a hundred kWh per year for electricity, and less than 10 therms per year for gas. Focusing on electricity, impacts of this magnitude would imply that one might want to be able to obtain a precision of ± 50 kWh/year on a savings estimate derived from random assignment of energy education to two groups. Given what we know about the year-to-year variability in electricity consumption in this population (the study group for PY2002 showed a standard deviation of about 1,200 kWh/year), this would imply that each group would need to comprise about 4,000 households in order to achieve the desired precision. Since statistical precision varies (inversely) with the square root of the study group size, higher precision would require much larger study groups.

These calculations are fairly rough ones based on simple pre/post analysis. It may be possible to achieve somewhat greater precision with smaller groups using regression models to control for other confounding factors. Nonetheless, it appears that at minimum, several thousand households in each of the two groups would be needed in order to measure energy education impacts from customer billing data in a meaningful way.

3.4.3 Persistence of impacts and the treatment of "movers"

With one exception (Harrigan and Gregory, 1994), the literature covered only impacts within the first-year from energy education. While Harrigan and Gregory found that the savings from energy education persisted through the third year following treatment, the persistence of these savings in other settings is unknown.

Moreover, though one could hypothesize that information transfer beyond the original client might occur, energy education is probably mainly tied to the client who receives it. If the client moves away, so does the energy education impact. Harrigan and Gregory confined their analysis to households that remained the same over the three-year period, as presumably did the other studies (the issue is not explicitly addressed in most). Nonetheless attrition of impacts from "movers" needs to be accounted for at some level. This analysis could be complicated, given that some households that change residence stay within the service territory (though perhaps with different end-uses than were affected by the program energy education), and some leave the service territory.

In practical terms, it would be difficult to track households that receive energy education and then change residences. One approach is to estimate energy education impacts based on stable households, with a *post hoc* adjustment for transient households.

3.4.4 Weather normalization

Some of the studies used methods such as the Princeton Scorekeeping Method (PRISM) to disaggregate space conditioning loads and correct for differences in the weather between the pre- and post-treatment periods, and some did not. (Some did not involve space heating or cooling loads at all.) In theory, the control group should account for variation in the weather, and therefore make explicit weather correction of usage superfluous. But if the energy education affects weather-sensitive loads, and the weather is unusually warm or cold during the analysis period, then the net savings derived from the analysis may not be in terms of average conditions unless weather normalization techniques are applied. The need for weather correction can be determined based on weather data at the time the analysis is conducted.

3.5 Conclusions and Recommendations

Our review indicates that obtaining solid estimates for the energy impacts of energy education could be a costly and time-consuming endeavor. The conclusions and recommendations discussed below summarize the results of this review.

1. Due to differences among program designs, energy education activities, housing stock and climate, the results from the reviewed studies cannot be applied directly to the LIEE program.
2. Quantifying impacts from energy education for the purposes of claiming program savings requires a high degree of rigor. A controlled experiment with a two-group approach is the most common approach to meet this standard.
3. The success of the two-group approach is dependent on ensuring that the treatment and comparison groups are equivalent in terms of demographics, house characteristics, climate and the penetration of specific measures. Weather corrections may be necessary if substantial deviations from normal weather occur during the analysis period.
4. To ensure that the savings estimates are unbiased, the sample must be sufficiently large and the participants randomly assigned to groups. This approach may be logistically difficult to implement in the LIEE program, since it would require withholding or delaying energy education for a subset of participants. Preliminary estimates suggest that sample sizes would have to be very large (several thousand) to be able to estimate savings within a useful degree of precision. Consequently, it is likely to be prohibitively expensive to pursue such a study.
5. The impacts of energy education are most likely to be achieved from the participants who received the service. In the LIEE population, however, some proportion of the participants are likely to move within a relatively short period of time. In practical terms, it would be difficult to track households that receive energy education and then change residences. One approach is to estimate energy education impacts based on stable households, with a *post hoc* adjustment for transient households. Even in stable households, the dearth of studies investigating the persistence of savings from energy education suggest that this effect remains an unknown quantity.
6. Before investing substantial resources in this type of quantitative effort, we recommend that a more qualitative assessment of energy education effects first be conducted. The first step is to establish clear, measurable goals and design process-related activities to assess the progress in meeting these goals. Such activities may include (1) review of a statistical sample of agency paperwork documenting energy education efforts, (2) participant observation of energy education delivery in the field for a sample of households, and (3) interviews with a statistical sample of households to obtain self-reports of behavior changes resulting from participation in the program. For the last, socially desirable responding is a concern in this context, but techniques such as those proposed by McRae (2002) could be used to mitigate this effect.

While the results of this research could not be expected to provide defensible quantitative estimates of the impacts from energy education per se, they would provide a fuller picture of how the program might be affecting participant behavior. These findings would also provide a better basis for deciding whether it is worthwhile to pursue the more difficult and expensive direct impact approach employed in the studies reviewed here.

3.6 References

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4 Data Collection and Issues

To conduct the analysis, the West Hill Team collected both hard copy and electronic program information, electronic utility billing data and additional documents, including the California Statewide Evaluation Protocols and the 2001 DEER Update Study.

In order to gain a better understanding of the program and the utilities' information systems, the team obtained and reviewed the following documents:

- program intake and inspection forms
- program description, policies and procedures
- program installation standards manuals
- database dictionaries for the program and customer tracking systems
- program information packets provided by each of the utilities

To complete the billing analysis, our team also requested from the utilities the following electronic information:

- premise level consumption data from 1999 through 2003 from each utility's customer information system for all of the premises that housed PY2002 participants
- daily weather data by weather station for the past thirteen years
- demographic data for PY 2002 participants from both the program tracking databases and the utilities' customer information systems
- premise level consumption data from 1999 through 2003 from each utility's customer information system for all of the premises that housed PY2003 participants for use in a comparison group
- equivalent demographic data for PY 2003 participants from both the program tracking databases and the utilities' customer information systems for use in a comparison group

Many conversations with utility staff covered diverse topics including interpretation and availability of data, the specifics of the energy education component, program implementation details and the characteristics of program participants.

The elimination of participants due to missing or incomplete data and the subsequent implications for the sample are discussed in section 7.3, Attrition.

4.1 Data Collection Process

The data collection process for this study was a somewhat lengthy one, beginning in January of 2004 and spanning the next seven months. The West Hill Energy Team requested a variety of program and other customer information from the utilities. Obtaining a complete set of the necessary program and billing data was an iterative process, as missing data were identified and subsequently provided by the utilities. While the bulk of the data had been supplied by April, missing data continued to be identified as late as the beginning of August.

During this process, the West Hill Team communicated with utility personnel most familiar with the database systems to clarify their understanding of the data and investigate possible data problems. Utility staff were cooperative and assisted us with sorting out the numerous issues arising from the data collection process.

The data sets themselves were extracted from the primary databases by the individual utilities and sent to West Hill Energy on CD. These data arrived in a variety of formats. All of the electronic data used in the analysis was migrated into a standard format with a uniform coding system.

4.2 Data Issues

The following discussion is framed in the context of the data needed for impact evaluations. We did not conduct a comprehensive review of the data procedures and management, as may be performed in a process evaluation. However, the data issues described below identify a number of areas where improvement is needed, both for evaluation and program reporting purposes. Through this process, a number of issues arose, falling into three broad categories: (1) the overall scope of the data collected through the program, (2) data collection procedures and (3) inconsistencies in specific fields. Each of these items is discussed below.

4.2.1 Scope of data collected

This issue relates to the nature of the program as currently implemented. The main objective of the program is to install all *feasible* (rather than cost effective) measures in participants' homes. In audit-driven programs outside of the low income sector, measures must often be demonstrated to be cost effective prior to installation. In these cases, detailed information is collected to conduct the measure screening and support the final offer. In contrast, the primary data collection needs of the LIEE program are related to demonstrating whether the measure is feasible, and typically consist of showing that the measure does not currently exist in the home. Under these conditions, the actual data necessary for program implementation is relatively simple and straightforward.

This aspect of the program creates some limiting factors for subsequent impact evaluations. If the evaluators are hired after the completion of the program year under review, they have no access to detailed pre-installation conditions in each home, sharply curtailing or eliminating the possibility of pursuing engineering or monitoring strategies. From a program implementation perspective, collecting detailed data on each site as part of the audit could introduce substantial additional costs to the program. It may be possible to obtain house-specific data from external sources at a lower cost, but the reliability of such data sources must be carefully considered. For these reasons, we recommend that evaluators be brought in *prior* to the program year to be reviewed if engineering or monitoring techniques are to be employed.

4.2.2 Program Data Collection Procedures

Even within the context of the program as implemented, a few key data needed for billing analysis do not seem to be consistently and reliably recorded. These additional data are related to the pre-installation conditions in the homes and should be able to be collected at the time of the site visit without adding a tremendous burden to the program implementers or program costs. These critical data include

- Fuel type used for space and water heating, and secondary space heating (if any)
- Presence of central air conditioning and whether the occupants report using it on a regular basis prior to the audit
- Number of room air conditioners present and number used regularly
- Type of all space and water heating equipment and whether it was in regular use prior to the audit, including furnaces, water heaters and electric space heating

This information should be added to the data collections forms (if necessary) and entered into the program tracking system. These data should also be verified at both the initial collection and data entry steps. These additional data needs are explained in more detail below.

4.2.3 Heating Fuel Types

Without knowing the fuel type used for space and water heating, it is not possible to ascertain the fuel expected to be saved by the conservation measures associated with these end uses. In other words, searching for electricity savings from showerheads in homes with gas water heaters is a fruitless task. This issue is more prevalent on the electric side, since the penetration of electric water and space heating is lower.

All of the utilities provided markers of the fuel types for water and space heating from their program tracking or billing systems. However, there was missing data for many participants in all utilities. Table 4-1 shows the assignment of the fuels for space and water heating and the number of accounts with missing fuel types in the final account sample from the utility information systems.

Table 4-1: Water and Space Heating Fuel Types for Final Sample

	% of Accounts in the Final Sample				Statewide Low Income Average[9]
	PG&E	SCE	SDG&E	Combined	
Water Heating					
Electric	7%	30%	7%	14%	8%
Gas	50%	27%	53%	43%	62%
Other	7%	1%	7%	5%	-
Missing	37%	42%	34%	38%	NA
Space Heating					
Electric	8%	36%	35%	19%	14%
Gas	49%	27%	57%	43%	68%
Other	6%	1%	1%	4%	-
Missing	37%	37%	7%	34%	NA
Total Accounts	28,709	15,073	4,090	47,872	

Our solution to this issue is explained in Chapter 6, Methods and Analysis, Section 6.4.1.

4.2.4 Pre-installation conditions for selected equipment

For some measures installed in the program, savings are not likely to be found from a billing analysis if the equipment was not functional or in use during the pre-installation period. Replacement and repair of furnace, hot water tanks, air conditioners and evaporative coolers are examples of such measures. The P&P manual specifically states the “non-feasibility” criteria, i.e., the conditions under which it is acceptable *not* to install the equipment. These protocols are listed in Table 4-2.

Using these standards, it would be perfectly reasonable for program implementers to install new air conditioners in homes with malfunctioning or completely nonfunctioning equipment, as well as to replace an older, working unit. If the program data identified those homes in which the air conditioner was in regular use prior to the new installation, this information could be incorporated into the analysis.

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[9] California Residential Appliance Survey

Table 4-2: Measure Installation Protocols[10]

Measure	Protocols
A/C Replacement	▪ Measure is not feasible if o A/C is present, operational, and less than 10 years old ▪ Install only in CEC climate zones 1, 6 through 8, and 16, or where temperatures regularly exceed 100
Evaporative Cooler Installation	▪ Measure is not feasible if o Existing evaporative cooler is operational ▪ Install only in homes with o operational, refrigerated A/C, and o in CEC climate zones 2 to 5, 9 to 15
Evaporative Cooler Maintenance	▪ Measure is not feasible if o Existing evaporative cooler is operational and does not require maintenance o Existing unit needs to be replaced for safety reasons ▪ If unit is not functioning, then it should be replaced ▪ Install only in CEC climate zones 2 to 5, 9 to 15
Furnace Replacement & Repair	▪ Measure is not feasible if o Furnace is properly functioning ▪ Home must be owner-occupied

4.2.5 Multifamily Buildings and Mobile Home Parks

Some multifamily buildings and many mobile home parks are served by a common meter. The program tracking data did not allow us to ascertain the total number of units and number of treated units in the building or mobile home park, which would be useful for interpreting the billing data. Consequently, many multifamily units and most of the mobile homes were excluded from the billing analysis. To be able to improve the scope of the billing analysis and further investigate the program impacts on mobile homes, the program tracking should include the total number of units and treated units in each multifamily building and mobile home park, and a mechanism for connecting specific participants to the correct building or park.

4.2.6 Other Data Inconsistencies

As tends to occur in the process of collecting billing data for multiple utilities, cleaning and preparing the data was complicated by inconsistencies in data collection across utilities. A host of minor issues arose and needed to be addressed, such as mislabeled measures, invoice date used as a proxy for the installation date, difficulties with matching weather data to the utility climate zones in the participant files and others. Some relevant data were collected by some utilities and not by others, limiting the potential for review of demographic data that could be consistently applied across utilities.

In addition to the items discussed above, and at a minimum, the following additional information should be collected by all of the utilities with a reasonably consistent

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[10] *Statewide P&P Manual*, pages 7.3.17 to 7.3.19 and D-1 to D-7.

definitions and format: number of occupants in the home, income category, housing type and senior citizen, and installation date. Verification procedures should be instituted or improved for these data.

4.3 Compliance with CPUC Decision 03-10-041

CPUC decision 03-10-014 emphasizes the importance of the evaluator's independence and states

> "Sampling and data collection tasks required for LIEE impact evaluations should be conducted by the contractor with the cooperation of the utilities." (at 2)

This requirement was interpreted to mean that the evaluation contractor must select both the specific fields to be used in the analysis and the sample group. To comply with this order, the evaluators needed complete access to all program participants for PY 2002 and the available data for the PY 2003 participants (for the comparison group.) The process was iterative, in that the data was provided by the utilities, reviewed by the evaluators and additional data provided as necessary.

The first requirement, i.e., selecting the fields, was relatively straightforward. The database dictionaries, providing a complete list and brief description of all fields, were eventually provided to the evaluators, allowing us to choose the most relevant fields. This method seems reasonably effective for addressing this component of the sampling process.

Our ability, however, to ascertain whether the participant data files are complete is limited. The utilities have the most detailed knowledge about their program and billing tracking systems. The evaluators are in a position of relying on the utilities for this information. To try to ensure that the PY 2002 program data sets were complete, we employed two methods: 1) to construct a list of measures installed in PY 2002 and request the utilities to verify the numbers and 2) to compare the data sets to the AEAP report filed by the utilities with the CPUC. The list of measures was distributed twice (once in May and again in July), and issues with the definition of the measure codes and the composition of the data sets were identified both times, resulting in a supplementary data set from one utility provided in August. The comparison to the AEAP reports worked reasonably well for three out of the four utilities, at least providing some assurance that the program data sets were complete.

The billing data presented a different set of challenges. Billing data were compared to the program data and internally checked for consistency. This process led to the conclusion that the billing records for a subset of participants were incomplete, and these records were later provided upon request. However, billing history was missing in its entirety for many participants, and we were unable to verify independently whether all of the available and requested billing data were provided. Given the complexity and size of the utilities' billing systems, we do not see an alternative to relying on the utilities for this information.

5 Approaches to LIEE Impact Evaluation

This chapter sets out to accomplish two objectives: (1) to describe best practices for estimating energy savings and (2) to discuss the various statistical and engineering approaches considered.

5.1 Best Practices

In 1994, the California Public Utilities Commission (CPUC) adopted the *Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Side Management (DSM) Programs* (Protocols) for the measurement and evaluation (M&E) of DSM programs. These guidelines focus on the critical elements of M&E, such as load impact estimation models, sampling, and metering, and are specific to various combinations of customer sectors, program types, and end uses. The newly released California Evaluation Framework builds on this experience and lays out a roadmap for future evaluation work in California. Consequently, the framework provides the basis for discussing the possible approaches that may be used for this and future LIEE evaluations. While the Framework suggests many options for analysis, data availability and quality limit the applicability of many of the Framework's methods. We discuss each evaluation approach in the context of the currently available data, and its constraints on the applicability of each evaluation method.

Impact evaluations are done primarily to confirm the energy and KW demand savings of each energy efficiency program. The Framework reminds us that the primary purpose of the evaluation is to measure the change in consumption of energy, and that it is not possible to measure the change in consumption directly, but only through comparison of a pre and post measurement of consumption. It is the evaluation's purpose to obtain the most accurate and unbiased estimate of that savings "…within a reasonable cost for the evaluation's needs and uses."

The Framework's discussion of this type of evaluation begins by introducing a number of factors that change the environment under which impact evaluations will be conducted in California. These include energy price volatility and uncertainty, the introduction of non-utility programs, and changes in the scope of some evaluations. The Framework also acknowledges that a number of conditions exist that complicate the analysis by affecting the environment within which these evaluations are conducted. Chief among these factors are the market noise created by overlapping program effects, spillover effects, free ridership, and the stated need to use impact evaluations as part of an integrated resource planning process. This latter issue may have significant effects on the timing and accuracy requirements of the analyses.

In formulating the models used in our analysis, we considered the following issues that were raised in the Framework discussion: (1) selecting the unit of measure, (2) selecting the impact model, (3) selecting the billing analysis model, (4) model specification, and (5) use of a comparison group.[11]

5.2 Selecting the Unit of Measure

One major decision that drives this and other impact evaluations is the unit of measure used to estimate program impacts. For many residential programs, it is sufficient to measure the energy savings on a household level basis. One of the most important indicators of program cost-effectiveness is the overall savings per household.

Household energy savings inform us about the overall effectiveness of the program. It is not sufficient, however, for determining which measures should continue to receive support and which items may no longer be cost effective. Measure assessment is conducted on a regular basis, and cost-effectiveness is balanced with non-energy benefits and, to a lesser extent, uniformity across utilities. Measure-level savings are a critical input into this analysis, and thus constitute the driving force behind the request to obtain savings estimates by measure and by house type. This higher level of disaggregation presents a number of challenges.

1. When the expected savings are a small fraction of the pre-installation energy use (referred to by Cohen (1988) as a small effect size), the ability of the model to detect these small savings are reduced.
2. When many of the items are installed in concert with other measures, it is difficult to isolate individual effects.
3. When the information collected on the individual measures is not always complete and/or accurate (e.g., fuel type for water heating and the operating condition of existing HVAC equipment), it is difficult to attribute savings to these measures.

As this chapter proceeds, we will discuss the trade offs between data availability and quality, and the ability to isolate savings to a particular installed measure.[12] Given the current set of data, it was not always possible to produce accurate and reliable results for each measure. This was particularly true of the water heating and space heating measures. In some cases, where the issues above were significant, we were only able to produce results at the end-use level.

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[11] For a more complete description of the various approaches to estimating gross energy impacts along with the pros and cons of each, see Ridge, et. al., 1994.

[12] Note that solution to small effect sizes is to increase the sample size. However, this could not be done since we were using all available participants.

5.3 Selecting the Right Impact Model

The Framework provides a roadmap for selecting the right impact model to use. The primary choice is whether to use billing analysis, engineering analysis, or some combination of both. As the roadmap indicates, billing analysis is generally used for large data sets where both pre- and post-period billing data are available and expected savings is greater than ten percent of total consumption. Engineering models are recommended where no pre-period data are available or when expected savings are small. As sample size increases, the ability of regression models to detect statistically significant savings of less than 10 percent increases. However, the savings for some LIEE measures are such a small percent of pre-installation energy use that even the large number of observations available in the LIEE evaluation will not provide sufficient statistical power.[13] In addition, some measures were almost always installed in combination, making it difficult to tease out the individual measure savings. Consequently, the billing analysis is able to provide robust estimates of aggregate program savings and savings for some of the measures with relatively large unambiguous savings but is not able to provide reliable estimates for each measure offered as part of LIEE.

Under ideal circumstances, with unlimited budgets, we might choose to use engineering methods to supplement the billing analysis. As an alternative, as is sometimes suggested, we could alternate the analysis annually by conducting billing analysis for one program year and selected engineering analysis for the next program year. This engineering analysis might include end-use metering of a sample of treated homes. Because this type of analysis is expensive, it is important to determine if the expense is justified by the anticipated gain in information. For LIEE, some of the end uses with the most uncertainty about their performance are the water and space heating measures which do not have large savings associated with them. To gain greater certainty regarding the savings for these measures, selected end-use metering studies may be worth pursuing in a future evaluation.

5.4 Selecting the Right Billing Analysis

The Framework describes a number of different billing analysis approaches to be considered, including the following[14]:

- Simple aggregate pre/post comparisons
- Statistically adjusted engineering (SAE) models
- Fixed effects—Analysis of covariance (ANCOVA) models.

Our process is to start with the simplest of these approaches and work towards developing separate fixed effect models for the electric and gas measures. We will

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[13] The power of a statistical test of a null hypothesis is the probability that it will lead to a rejection of the null hypothesis when it is false, i.e., the probability that it will result in the conclusion that the phenomenon exists. (See Cohen, 1988; Kraemer, Chmura and Thiemann, 1987; Lipsey, 1990.)

[14] The Framework also refers to the conditional demand analysis (CDA). This method tends to be very expensive and is not often employed for the type of impact analysis required for the LIEE.

provide more detail with respect to the specification of the fixed effect models in the following section. Of the three options listed above, we have excluded SAE models as a possible option since building simulations, end use metering and other data needed for SAE models are not available in this project.

5.5 Model Specification

The Framework lists a variety of issues that affect the applicability, reliability, and validity of regressions. We have considered each of these and developed a plan to address each issue that applies. The potential problems and our approaches to solving them are discussed below.

- Misspecification: This covers large areas of regression misapplication in which the model chosen omits relevant explanatory variables, includes irrelevant explanatory variables, ignores qualitative changes in explanatory variables, or accepts regression equations with incorrect mathematical form. We have carefully selected each variable as to its relevance and consistency. We acknowledge that there are some variables for which data are not available or for which problems exist. Accordingly, we devote significant attention to testing the sensitivity of the findings and trying alternative models.

- Measurement error: There are two basic kinds of errors that affect empirical measurements*: random error* and *non-random error*.

  Random is the term used to designate all of those chance factors that confound the measurement of any phenomenon. The amount of random error is inversely related to the degree of reliability (precision) of the measurement instrument. That is, a highly reliable indicator is one that leads to consistent results on repeated measurements because it does not fluctuate greatly due to random error. The effects of random error are totally unsystematic in character.

  The second type of error that affects empirical measurements is non-random error. Non-random error has a systematic biasing effect on measuring instruments. Thus, an engineering prior that contains non-random error is one that, in repeated measurements, always results in either underestimates or overestimates of HVAC savings. Non-random error is very much related to the concept of validity (accuracy) which is defined as the net difference between the obtained measurement and the true value. Just as reliability is inversely related to the amount of random error, so validity depends on the extent of non-random error.

  In any given study, it may be the case that some of the variables being measured cannot be measured accurately, either because of data collection difficulties or because they are inherently difficult to measure. Random errors in measuring the dependent variables are incorporated in the disturbance term and their existence causes no problems. However, when the random errors are in the independent variables, the problems become quite serious, resulting in biased estimates.

This study had ample opportunity for both types of errors to occur because data are being collected by four different utilities and many service contractors. To the extent we could, we specified both program-wide and utility specific models to see if utility differences exist. We do not have all the data we would need to build models that differentiate results by contractor. Keep in mind that when we found variations between utilities, we had no way of determining if they were real and the results of different practices, housing types or climate, or differences that occurred because of variations in the measurement approaches used by each utility.

For example, we had imperfect information regarding the fuel for water heating. Modeling water heating-related kWh savings while including households that used natural gas to heat their water will clearly understate the kWh savings. Another example is that we had no way of eliminating customers from the various models whose existing HVAC equipment was not functioning prior to the installation of new efficient HVAC equipment. In such cases, rather than a decrease in energy use, we would expect an increase in energy use. Unfortunately, such customers could not be identified and were retained in the model, resulting in somewhat conservative estimates of savings.

- Autocorrelation: While ordinary least squares (OLS) models assume that error terms are independent, models using time-series data (e.g., monthly energy consumption for a given household) often violate this assumption. The consequence of uncorrected autocorrelation is typically higher calculated statistical precision than is actually the case. We tested our models using the standard test (Durbin-Watson test) for autocorrelation. We also employed bootstrapped estimates of statistical precision to eliminate the main source of autocorrelation, i.e., consecutive monthly energy consumption within households. We note that the Framework describes other situations, besides time-series data issues, where autocorrelation can be an issue. However, the use of a fixed effects/ANCOVA or a least squares dummy variable (LSDV) model can mitigate this issue.

- Heteroscedasticity: The model assumes that the variance of the error term is constant, however, in this cross-sectional study, the size of the home, household size, or income may create residuals with greater variance as the size of one of these variables increase. The fixed effects model controls for size effects and the use of a fixed effects/ANCOVA or a least squares dummy variable (LSDV) model mitigates the effects of heteroscedasticity.

- Collinearity refers to the situation where two or more independent variables in a model are highly correlated, such as when two measures tend to be installed together. Collinearity results in higher variances for both predicted and explanatory variables. It also creates difficulty in partitioning variance among the competing explanatory variables. First, however, the problem must be detected. There are several ways to approach this task.

We used the following three approaches to detecting collinearity: (1) significant correlation between pairs of independent variables in the model, (2) nonsignificant t tests for individual beta parameters where the F test for overall model is significant, and (3) opposite signs from what is expected in the estimated parameters.

Once detected, there is no consensus on what to do about it. Some recommend doing nothing. Others recommend obtaining more data, which, given both time and budget constraints, is unfeasible. Omitting one of the variables implicated is perhaps the most common approach. However, this makes sense only if the true coefficient of the omitted variable is zero. If the true coefficient of that variable is not zero, a specification error is created. Yet another approach is to group the collinear variables together to form a composite index capable of representing the group of variables by itself.

- Use of a Comparison Group: Some utility evaluation experts have recommended that the basic time series and pre/post designs be enhanced through the use of a comparison group of customers to address non-program effects. Data are generally not available to model all of the non-program effects and even after controlling for many of the historical factors, there is always the possibility that something else happened in the environment that affected consumption. To attempt to control for any of these remaining historical effects, one could include a comparison group of customers who did not install measures during the period being studied.

  Whenever one mixes two groups together that have different characteristics, these differences must be statistically controlled. If the observed differences between the two groups cannot be effectively controlled statistically, then the effect of history is imperfectly captured and the resulting net impact due to the installation of the equipment is biased in unknown ways. For the LIEE program, the use of the 2003 participants prior to receiving measures through the program as the comparison group for PY2002 was designed to minimize the differences between the two groups.

  There are also the additional costs of collecting the necessary data from non-participant non-installers. In this case, the billing data for the 2003 participants was readily available and did not add substantial additional costs to the project.

  Comparison groups are often used to estimate the net program impacts, i.e., the impacts after non-program effects such as free ridership and spill over have been addressed. For the LIEE program, as is common with low-income programs, the net and gross impacts are assumed to be equal, i.e., low income residents would generally not be expected to install measures in the absence of the program. However, if this assumption is not borne out, the inclusion of the comparison group may introduce some net effects into the analysis.

5.6 Engineering and Metering Methods

Deemed savings are typically based on engineering estimates, often developed from simulations of whole building energy use. The underlying assumptions do not relate to any specific building, but may be more or less accurate for the general population. Improving these estimates requires detailed pre-installation baseline data. For engineering strategies, the baseline would entail a detailed description of the pre-installation conditions, such as the results of a blower door test (for infiltration measures), the quantity and condition of the pre-existing insulation, or the number of gallons per minute used by the existing showerhead. For metering, the pre-installation baseline would be the metered amount of energy used by the equipment prior to the installation.

Under the LIEE program as currently delivered, this baseline information is unavailable, and is not necessary to collect for the purposes of program implementation. Given these considerations, the participating utilities have two possible approaches to pursuing engineering or monitoring strategies:

- Incorporate the collection of baseline data into the program to assess existing conditions for all participants, or
- Collect the baseline data for a representative sample of participants

Either approach is likely to involve substantial costs and a long lead time. Since this program already contains an on site component, it would be possible for contractors to collect this baseline data, but the increased delivery costs could be substantial, possibly prohibitive. Evaluators will need to design the sample and data collection prior to implementation for the program year to be evaluated.

While engineering and metering methods are effective strategies for developing measure-level estimates, even for measures with relatively small impacts, the potentially high costs and extended time frame should be weighed against the value of developing more precise measure-level estimates for this program.

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6 Methods and Analysis

This chapter describes the models and application of those models to the actual data set. In this chapter, we cover the procedures and approaches that we adopted in the course of the analysis due to the characteristics of the actual data. This chapter is organized into nine sections: sample plan and weighting, simple pre/post modeling, regression modeling, specification of the regression model, results of diagnostics, comparison group sampling, a discussion of premises and accounts, and a comparison of our analysis to previous evaluations.

6.1 Sampling Plan and Weights

Data sets are needed for the utility electric models, the composite gas model, and for other models built for single measure analysis. For each of these models, we did not select samples from the available data, but instead used all of the eligible accounts with sufficient billing data. Using all available accounts removes many complications involved in sampling design, weighting, and analysis, while in this case adding very little in additional processing effort. Attrition is discussed in detail in Chapter 7, Results, Section 7.3.

6.2 Simple Pre/Post Modeling

The first step is to estimate total annual household savings or annual savings for specific measures through a simple pre/post analysis of participants and comparison group. The change in the household usage for participants is calculated as follows:

$$\Delta U = U_{pre} - U_{post} \tag{1}$$

Where

ΔU average annualized change in usage per participating household (kWh or therms)

U_{pre} average annualized pre-installation usage of participants (kWh or therms)

U_{post} average annualized post-installation usage of participants (kWh or therms)

The participants' savings are calculated as follows:

$$S = \Delta U_p - \Delta U_c \tag{2}$$

Where

S average annualized savings per participating household (kWh or therms), positive S indicates savings

ΔU_p average annualized change in use for participants (kWh or therms)

ΔU_c average annualized change in use for the comparison group (kWh or therms)

The comparison group, consisting of 2003 participants during the period prior to their treatment through the program, is used to adjust for changes in energy usage due to non-program influences. The change in use for the comparison group is calculated for periods set to correspond to the participants' pre- and post-installation billing. The process for selecting the control group is described in more detail in Section 6.7 and Appendix A-3.

6.3 Modeling Approach: Regression

The discussion on regression covers a brief description of the general form, a list of the predictor variables, confidence intervals, model diagnostics and references.

6.3.1 General Form

Estimates of measure savings are obtained from fixed-effects models of monthly electricity and natural gas usage, similar to the models used in impact evaluations of the the 2000 and 2001 participants. The general form of these models is

$$C_{it} = \alpha + \mathbf{x}_{it}\boldsymbol{\beta} + \upsilon_i + \varepsilon_{it} \qquad (3)$$

Where

C_{it} monthly consumption for the premise *i* in period *t*, expressed in kWh or therms per day

α constant

$\mathbf{x}_{it}$ a collection (vector) of predictor variables for premise *i* in period *t* (described below)

$\boldsymbol{\beta}$ a collection (vector) of coefficients that quantify the average influence of modeled program measures and other non-program factors on monthly consumption

υ_i a premise specific residual not explained by the model. This residual varies across premises, but is constant for any given premise, and represents unexplained household-to-household differences in usage due to differences in appliance holdings and lifestyle.

ε_{it} the "usual" residual; i.e., a term that accounts for the difference between the model estimate and actual consumption for any particular premise and time period after also removing the premise-specific residual

The "fixed-effects" aspect of the model arises from including the υ_i term. This term postulates that some households generally use a lot of electricity (or natural gas) and some households use very little. Since our interest lies more in understanding how the installation of program measures (and other factors) *change* usage within households, rather than why some households have generally higher usage than other households, these level differences from household to household are of little direct interest, and are removed by the fixed-effects model.

In fact, the above fixed-effects model is algebraically equivalent to an ordinary linear regression with the mean values for each premise removed from both the dependent and independent variables:

$$(C_{it} - Cavg_i) = \alpha + (\mathbf{x}_{it} - \mathbf{x}avg_i)\boldsymbol{\beta} + \varepsilon_{it} \qquad (4)$$

In this sense, the model can be viewed as an attempt to model program and non-program factors that cause usage to increase or decrease relative to average consumption for each premise.

6.3.2 Dependent Variable

The dependent variable in the cross-sectional, time series model described above is the recorded kWh and therm consumption for the participating premises from the beginning of the analysis period (late 2000) through the end of 2003. This period covers a years' worth of billing data before and after the PY 2002 installations. The kWh and therm data are in billing cycle frequency. The kWh and therm use is divided by the number of days in the billing cycle and then multiplied by 365 to create annualized kWh and therms.

6.3.3 Independent Variables

The regression analysis is based on a dummy variable approach, in which the **X** values are 0's or 1's and the coefficients (β's) correspond to the savings or usage associated with the variable. The independent variables for the electric model include some combination of the following.

- End uses of the measures installed through the program (lighting, refrigeration, cooling, hot water, and space heating)
- Monthly dummy variables to account for non-program related changes in usage reflected by the comparison group (electric model)
- Annual dummy variables to account for non-program related changes in usage reflected by the comparison group (gas model)
- Cooling Degree-days (CDD): Billing files were merged with weather station files so that the appropriate weather data could be attached to each customer living in the area covered by the weather station. If the average daily

temperature was not provided by the utility, it was calculated by adding the day's high and low temperatures and dividing by two. If the number is below a temperature set point of 65, for example, there are no cooling degree-days that day. If the number is greater than 65, 65 is subtracted from it to find the number of cooling degree-days. For example, if the day's high is 90 and the day's low is 70, the day's average is 80. Eighty minus 65 is 15 cooling degree-days. Set points of 70 and 75 were considered, and 75 was selected for the analysis. This variable was also standardized to a daily value per billing cycle.

- Heating Degree-days: The process was similar for heating degree days, using a base temperature of 65
- CARE designation: A variable was created for *each* customer observation that indicated whether the customer was on the CARE rate; the variable was set to 1 if the read was marked as a CARE rate, and 0 otherwise
- After the initial stage of end-use modeling was completed, we investigated the value of designing a more detailed regression model for a subset of participants by adding the measures installed to the list of predictor variables; details regarding the variables included in the final models are given in Section 6.4.2 below

Lists of the specific variables used in each model are given in Section 6.4.2, Tables 6-1, 6-3 and 6-5.

6.3.4 Confidence Intervals

Confidence intervals for the coefficients can be directly obtained from the fixed-effects model-fitting routines in our statistical software packages. However, there may be cases where autocorrelation has been only partially mitigated by the fixed-effects ANCOVA model. Autocorrelation tends to minimize the variation and can result in unrealistically tight confidence intervals.

For these reasons, we obtained confidence intervals using the bootstrap technique. The bootstrap is a computer-intensive, empirical approach to estimating uncertainty. Its major advantage is that it relies on only one assumption, i.e., the data set in hand is a reasonable approximation of the larger population for which we are trying to make inferences.

The bootstrap works by simulating the process of drawing a sample and estimating a model to get an empirical estimate of the sampling error in the results. The process works as follows:

1. Draw a sample of premises (with replacement) of the same size as the study group.
2. Estimate the model on the sample, and store the results.
3. Repeat Steps 1 and 2 many times to obtain a collection of estimates. The number of iterations may range from a few hundred to many thousands, depending on how confidence intervals are to be estimated.
4. Use the variation (typically the standard deviation) in results across the collection of estimates to estimate the uncertainty in the original results.

Based on the assumption that most of the uncertainty in the results arises from differences from household to household in the impact of the measures, we resample at the account level, and include the entire consumption history for each sampled account. Sampling "with replacement" means that any given account (and its consumption history) may appear multiple times in a given iteration.

A comparison of the standard errors produced through the bootstrapping and regression analysis is presented in Section 6.5.4.

6.3.5 Model Diagnostics

Outliers and influential data points can be an issue with regression models, particularly if only a small number of households receive a measure of interest. In addition, if measures are typically installed concurrently or are correlated with other household characteristics, it can be difficult to separate their influences on usage, a problem known as collinearity.

To understand the extent to which these issues affect these analyses, we employed the following analyses:

- We determined the extent to which individual data points influenced the values of model coefficients. We used the DFFITS procedure, which calculates a predicted value two ways, once with a potential influential observation and once without it. If there is a large difference between the two, the case is considered influential. Typically, observations with a value of DFFITS exceeding 2 are considered to be influential. Given the high number of observations, the cut off level was modified to reflect the number of variables and observations in the analysis, as recommended by Belsley, Kuh and Welsch (1980). This adjustment was set at 2 x square root(p/n), where p is the number of variables and n the number of observations.

  In our analysis, the observations were the monthly billing reads, but the experimental unit is the household. Consequently, two methods were used to identify the influential households: (1) the average DFFITS for the household was above the size-adjusted and (2) 25% of the monthly observations for the household were above the size-adjusted DFFITS cut off.

  Once detected, these households were removed and the regression analysis run to assess their impacts on the results. Retaining the outliers in the analysis but assigning a lower weight than was assigned non-influential observations was also tried. The weight used, developed by Welsch (1980), is as follows:

$$w_i = 1 \quad \text{if } |\mathrm{DFFITS}_i| \le 0.34 \tag{3}$$

or

$$w_i = \frac{0.34}{|\mathrm{DFFITS}_i|} \quad \text{if } |\mathrm{DFFITS}_i| > 0.34 \tag{4}$$

Due to the high number of observations, the cut off of .34 recommended by Welsch did not result in the removal of any outliers. For this reason, the size-adjusted cut off described above is used as the weighting factor.

The DFFITS analysis was conducted on the final models, but the customer-specific intercepts were omitted due to the limitations of the SAS software.

- Another method used to assess the impacts of outliers is based on the measure of how much an individual data point affects a single model coefficient (DFBETA). A DFBETA of 1.0 on a particular model coefficient for a given observation means that omitting that observation from the analysis will result in the coefficient changing by one standard error. The larger the absolute value of the DFBETA, the more influence the observation has on the determination of the model coefficient.

  As the number of observations in the analysis increases, the impact of any particular observation on the model coefficients goes down; therefore analysts typically set the threshold for what constitutes an influential observation as a function of the sample size. We used the common convention of |DFBETA| > 2/sqrt(n) as the threshold. Moreover, since we are more concerned about influential homes than individual monthly data points, we calculated the average DFBETA by account, and ran the DFBETA-screened analysis omitting all data for accounts where the average DFBETA exceeded the threshold.

  Differences between the DFBETA-screened runs and the base model reflect what happens when the most influential data points for a particular coefficient are omitted. The results thus provide a sense of the extent to which a particular coefficient is determined by a small number of accounts in the analysis.

  Note that the DFBETA-screened coefficients are actually a compilation of separate runs in which the influential accounts for a particular coefficient are dropped. Only the coefficient for the variable of interest is reported for each run. Thus, it is not possible to determine from this analysis the impact of removing those outliers on the values of the other coefficients.

- To identify potential first-order collinearity problems, we examined the correlation matrix of predictors. A number of alternative models were tried, and measures which were highly correlated with other measures were bundled, as described in section 6.6 below.

6.4 Specification of the Regression Model

The savings estimates were developed using three regression models: two for electric measures and one for gas. The comparison group selected through the simple pre/post analysis described above was also included in the regression models. The entire comparison group was incorporated into the gas and the electric base model, and a subset was used in the electric cooling models, as explained below.

For the electric models, the regression analysis is divided into two parts: base measures (refrigeration, lighting and water heating conservation) were estimated by utility, and the cooling measures analyzed separately for PG&E and SCE. By separating the cooling measures, we were able to minimize the number of confounding factors in the analysis while still maintaining a high proportion of the sample participants who installed cooling measures.

One composite model was developed to estimate the gas savings. For the gas measures, the variation in weather over the entire territory covered by the three gas utilities is needed to provide more reliable measure-level estimates. In contrast, the electric base model is far less affected by weather impacts, and the SCE and PG&E cooling models both exhibit a wide range of summer temperatures.

As described in the above in Section 6.3.1, customer intercepts are incorporated into all of the models. These intercepts account for the fixed characteristics of the home, such as house size and presence of major appliances. The customer intercepts explain a large part of the fluctuations in usage, and consequently the R-squared statistic for these models tends to be high.

6.4.1 Identifying Fuel Types for Space and Water Heating

As discussed earlier, the utility data identifying the water and space heating fuels used in each home are missing for a substantial portion of the participants (about a third). (See Table 6-1 in Section 6, Data Collection and Issues.) This piece of information is important for two reasons: (1) to be able to estimate the savings for electric and gas space and water heating measures and (2) to model effects specific to homes with space or water heating.

We considered three approaches to address the uncertainty associated with the fuel type designators:

- Estimating water and space heating savings for all participants regardless of fuel type
- Using the fuel type designators provided by the utilities
- Assigning fuel types to homes on the basis of usage levels and patterns

Since there is some uncertainty associated with the fuel types, all of these options introduce random error into the model, having a downward effect on the coefficients. The first option is the simplest, however it was rejected because the high level of error associated with this method (particularly in the electric model) made it impossible to identify savings from water and space heating measures.

Using the third approach, the monthly usage patterns in each home are reviewed for magnitude and seasonal variations. Criteria are established for defining homes with electric space and water heating, and then the fuel type is assigned to each home meeting the criteria. The criteria must be set high enough to capture primarily homes with these electric (or gas) end uses.[15]

Our team is concerned that this strategy is likely to introduce systematic error to the model, in addition to the random error. Since the screening process would be likely to eliminate homes with lower usage (and probably lower savings), the savings may reflect the savings in homes with high use rather than the savings for the broader participant base.

While all of these options have shortcomings and will result in some degree of misspecification of the model, we settled on the second option as the best choice, since there is no evidence it would introduce systematic error to the analysis and it also enabled us to develop savings estimates for hot water and gas space heating measures.

6.4.2 Model Variables

The regression models contain one observation for each month during the analysis period. This approach allows the model to account for the monthly and seasonal variations in usage. The dependent variable is annualized kWh (daily kWh for the period multiplied by 365 days.)

The independent variables included in both components of the regression analysis are listed in Table 6-1 below. (The cooling and base variables are defined in those sections.) To estimate measure savings, we interact a number of variables with a dummy variable dpost, which defines the pre and post periods. All variables interacted with dpost are set to zero during the pre period and one (or a specific value, such as the number of lighting products installed) for the post period. All savings terms interacted with heating or cooling degree days are multiplied by the average daily degree days for the participants with the measure to obtain the annual kWh savings.

The details of the development of the weather variables are provided in above Section 6.3.3. Water heating savings are estimated only for those homes identified by the utilities as having electric or gas water heat. The variable estimating the change in use in homes with electric space heat is also assigned according to the utilities’ designators.

Many methods of estimating savings related to the space heating measures for homes with electric space heat were considered, but no savings were found for these measures. In fact, there appeared to be a substantial increase in usage associated with these measures. Further analysis indicates that homes with electric space heat on average, with or without measures, in both the comparison and the treatment groups, show a proportional increase in electric consumption as temperatures dip. A variable (ishload) was included to account for the changes in heating load in homes with electric space heating.

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[15] Xenergy used a hybrid system, relying on the utility designators when they deemed to be sufficiently reliable and the assigned fuel types in all other cases.

Table 6-1: Common Variables in All Models

Variables in All Models (Electric Cooling and Base Models & Gas Model)		
Variable Name	Interaction	Meaning
Dpost		Dummy variable, 0 for the pre period, 1 for the post period; interacted with measure variables to estimate savings and other differences between the pre and post periods; *not included in the final model*
Nhdd		Average daily heating degree days for the period; reflects change in usage associated with colder temperatures
Nhddmf	Nhdd*mf	Same as above for multifamily homes
Dcare		1 if the participant was on the CARE rate for that month, 0 otherwise, reflects impact of the Care rate on usage
Carepost	Dcare*dpost	Change in the usage associated with the CARE rate from pre to post installation periods
Icareposthtg	Dcare*dpost *nhdd	Heating-sensitive post-period CARE impacts
Variables in the Electric Models Only		
Variable Name	Interaction	Meaning
Ncdd		Average daily cooling degree days for the period; when multiplied by the average CDD, it reflects the additional (or reduced) usage associated with the increase in temperature
Ncddmf	Ncdd*mf	Same as above for multifamily homes
Icarepostclg	Dcare*dpost *ncdd	Cooling-sensitive post-period CARE impacts
Ishload	Esh*dpost *nhdd	Heating-related variation in usage in homes with electric space heat

In addition to the variables listed above, the electric model includes monthly dummy variables. There is one variable for every month and year in the analysis period, and the dummy is set to one if the read is in that period, or zero otherwise. This approach allows us to account for the monthly variation in usage that is not related to the program or other known factors.

6.4.2.1 Electric Base Model

This model is used to estimate the savings from efficient refrigerators, lighting and hot water conservation measures. Only participants with cooling measures are excluded from the analysis. The comparison group selected for the simple pre/post analysis is also incorporated into the regression model. Over 90% of SCE's, and 75% of PG&E's, sample participants with base measures are included in the model.

Table 6-2: Base Model Sampling

	Total # of Households in Sample	# of Households in Base Model	% of Sample in Base Model
PG&E			
Total Households	28,618	22,698	79%
Refrigeration	7,658	5,611	73%
Lighting	28,080	22,197	79%
Hot Water Conservation	1,627	1,220	75%
Space Heating Conservation	1,668	1,267	76%
SCE			
Total Households	12,688	12,329	97%
Refrigeration	6,073	6,031	99%
Lighting	7,710	7,400	96%
Hot Water Conservation	314	297	95%
Space Heating Conservation	935	916	98%

Based on the regression output, the coefficients for the listed variable are highly significant in all of the base models (for each utility and for the combined utilities), with the exception of the variables related to the CARE rate, which tend to vary in significance, magnitude and sign, suggesting that collinearity may be an issue. The R-squared values for these models ranged from .78 (SCE) to .85 (SDG&E), with the values for PG&E and the combined utility model at .79. The detailed output from the regression analysis is provided in Appendix A-1.

Table 6-3: Variables in the Base Electric Model Only

Variable	Interaction	Measure Estimated	Meaning
Nref	ref*dpost	Refrigerator	1 if a refrigerator was installed, 0 otherwise
Nltgprd	Ltgprd*dpost	Lighting	Number of lighting products installed
Ndhw	Dhw*dpost	Hot water package	1 if any hot water measure was installed in a home with electric water heating, 0 otherwise

6.4.2.2 Cooling Model

For PG&E and SDG&E, the cooling model comprises all participants with a cooling measure and no electric space or water heating measures. Using these criteria, over 90% of the sample participants with cooling measures are included in the model.

A subset of the comparison group is used in this part of the analysis, with the same proportion of comparison group members to participants as in the overall model (about 1 to 4). This subset is randomly selected from the sample comparison group using a four category stratification. The four strata are defined to match the summer usage distribution of the treatment group. Table 6-4 shows the total number of households in the participant sample and the cooling model by measure. As can be seen from this table, all of the cooling measures are well represented in the model.

Table 6-4: Cooling Model Sample

	Total # of Households in Sample	# of Households in Cooling Model	% of Total in Cooling Model
PG&E			
Total Households	6,011	5,471	91%
Evaporative Coolers	5,461	4,976	91%
Evaporative Cooler Maintenance	448	393	88%
A/C Replacement	183	179	98%
Base Measures[16]	5,916	5,380	
Comparison Group		1,500	
SCE			
Total Households	2,744	2,725	99%
Evaporative Coolers	114	114	100%
Evaporative Cooler Maintenance	1,741	1,741	100%
A/C Replacement	933	914	98%
Base Measures	342	340	
Comparison Group		700	

Table 6-4 shows the additional variables included in the cooling model, reflecting the installation of the three cooling measures. A variable was included to account for the base savings from lighting and refrigeration measures. The savings for these measures were estimated directly from the base model.

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[16] The non-weather sensitive measures for participants with cooling installations are lighting and refrigeration.

Table 6-5: Variables in the Cooling Model Only

Variable	Interaction	Measure Estimated	Meaning
Nbase	Base*dpost		Reflects savings associated with lighting or refrigeration measures; not used to estimate savings for these measures
Nevap	Evap*dpost *summo	Evaporative cooler installations	1 if an evaporative cooler was installed and the read period is during the cooling season (May to September), 0 otherwise; reflects non-weather sensitive seasonal savings for evaporative coolers
Ievap	Evap*dpost *ncdd	Evaporative cooler installations	Daily CDD during the post-period for homes with evaporative coolers installed; reflects change in usage as temperatures increase
Ievapm	Evapm*dpost *ncdd	Evaporative cooler maintenance	Same as above for homes with evaporative cooler maintenance
Iac	AC*dpost *ncdd	A/C Replacement	Same as above for homes with A/C replacement

From the regression output, most of the coefficients for the listed variables are highly significant in both of the cooling models, with the exception of the some variables related to the CARE rate. The SCE model has an R-squared of .73, and the value for PG&E is .76. The detailed output from the regression analysis is provided in Appendix A-1.

This method was not effective for estimating savings for SDG&E's cooling measures, most likely due to the mild weather conditions, the combinations of measures installed, the general uncertainty with the savings from air conditioner replacements and the relatively small number of measures installed (145 air conditioner replacements in the sample).

6.4.2.3 Gas Model

The gas and electric models are similar, relying on the same set of variables to the extent that it is appropriate. Monthly dummy variables were not included in the gas model due to the natural seasonal fluctuations in gas usage. However, there appears to be a trend of increasing energy usage during this analysis period. Three dummy time variables for years 2001, 2002 and 2003 were added to account for these variations.

Attic insulation, duct repair and programmable thermostats are modeled separately, as are furnace replacement and heating system maintenance. Based on deemed savings estimates from the DEER report, these measures would be expected to have significant savings that could be identified in the regression analysis. All other space heating measures are rolled into a single aggregate variable.

Savings from attic insulation are estimated by comparing the use in insulated homes to those receiving insulation through the program. Since program protocols require the installation of all measures wherever feasible, homes not treated in PY 2002 are assumed to be fully insulated. Given that it may not be possible to install insulation safely in some of the participating homes, this assumption may introduce some error into the analysis.

The combination of gas space and water heating was prevalent in the LIEE homes. As in the electric model, this coincidence of space and water heating load creates difficulties in separating the savings from water and space heating measures. Changing the mix of variables in the model tends to affect the relative magnitude of the savings from water and envelope measures.

6.4.2.4 Weather Normalization

The heating and cooling degree day variables in the regression model are calculated for the read period. The utilities provided daily high and low temperatures from 1991 through 2003 by weather station, and these data are averaged and summed to obtain the heating and cooling degree days for each read period. The weather station associated with each participant's home is identified in either the program tracking data or the billing data (depending on the utility). The program and weather data are merged with the billing history for use in the regression model.

The coefficients for all variables interacted with cooling or heating degree days are multiplied by the ten-year normalized degree days for the weather station to obtain the estimated energy savings. For the weather-dependent measures represented by a separate variable in the regression model (such as duct repair, attic insulation and air conditioner replacement), the savings are estimated by determining the savings for each home in the sample using the normalized degree days for the weather station, and then averaging the results by utility and by housing type. Thus, savings by house type reflect the weather-specific conditions for that subset of participants. The distribution of the savings for the aggregated variables is explained in Section 6.4.2.6.

For the cooling models, the savings are adjusted to reflect the weather effects for the total participant group by averaging the measure savings by CEC building climate zone and housing type for the entire participant base. The average savings for the gas space heating measures are reasonably consistent between the regression sample and total participant group, obviating the need to make any further adjustments to these savings estimates.

Table 6-6: Variables in the Gas Model Only

Variable	**Interaction**	**Measure Estimated**	**Meaning**
Gasheathdd	Gasheat*hdd		Weather-sensitive variable accounts for gas space heat usage
Gasheathddmf	Gasheat*hdd *mf		Same as above for multifamily homes
gasheathddtime	Gasheat*hdd *Time		Reflects change in gas space heating usage over time
Iainsul	Ainsul*hdd *dpost + (existing insul) *hdd	Attic insulation	Weather-sensitive savings for homes with attic insulation and gas space heating; models all homes with attic insulation; savings estimated by comparing homes with existing attic insulation to those receiving insulation through the program
Ifurnrep	Furnrep*hdd *dpost	Furnace replacement	Same as above for homes with furnace replacement
Ihsmnt	Hsmnt*hdd *dpost	Heating system maintenance	Same as above for homes receiving heating system maintenance
Itstat	Tstat**hdd *dpost	Programmable thermostats	Weather-sensitive change in use for homes receiving programmable thermostats and having gas space heating; reflects change in usage as temperatures decrease
Iducts	Ducts*hdd *dpost	Duct Repair and sealing	Same as above for homes receiving duct repairs and sealing
Ishother	Shother*hdd *dpost	Other envelope and space heating measures	Same as above for homes receiving at least one other envelope or heating system measure
Ndhwcons	Dhwcons *dpost	DHW Conservation Measures	Dummy variable set to 1 for homes with at least one DHW conservation measure and gas water heating, 0 otherwise
Ndhwrep	Dhwrep *dpost	DHW Replacement	Same as above for homes receiving a new gas DHW tank

6.4.2.5 Housing Types

One of the requirements of the evaluation is to provide savings estimates by housing type. However, we found that defining variables by housing type in the regression model did not produce useful results, possibly due to the increase in the number of variables and the number of observations with missing data for this field.

For many measures, such as refrigeration and lighting, we do not have sufficient information regarding the characteristics of the homes and the equipment installed to conclude that there would be real differences in savings among the three housing types. For heating and cooling measures, it is reasonable to assume that the weather-related loads are different, with the loads and subsequent savings found in multifamily homes generally being smaller than the loads and savings found in single family homes.

The regression analysis shows the relationship between multifamily and single family heating and cooling loads. The heating and cooling degree variables in the model provide a method to estimate the relative heating and cooling loads for multifamily and single family homes. These terms absorb the weather-related changes in usage. In the cooling model, for that set of participants where we have reliable information that the household does have cooling equipment, the NCDD variable primarily represents the proportional increase in electric load associated with the use of this equipment as the temperature increases.[17] This term can be used to compare the proportional fuel use for single family and multifamily homes. The same process applies to the gas space heating load. This approach is used for all cooling measures, and the individually-estimated space heating measures in the gas model.

Based on this analysis, cooling measures in multifamily homes are assumed to save 70% of the single family savings, and space heating measures in multifamily homes with gas space heat are assumed to save 40% of the savings in single family homes.

Estimating savings separately for mobile homes is complicated by a number of factors. First, the attrition among mobile homes in the regression sample is high since mobile home parks are commonly master-metered. Thus, even attempting to assess heating and cooling loads for mobile homes is not a possibility. The DEER report also does not provide a break out of savings for mobile homes. Given the similarities between mobile and single family homes, the savings for these two housing types are assumed to be the same.

For water and space heating measures in which the deemed savings are used to distribute the aggregate regression results to the measure level, the multifamily and single family savings are based on the estimates for these subsectors provided in the DEER report.

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[17] This variable may also capture the rise in electric usage with temperature for other reasons, such as increased fan usage, but the impact is likely to be small.

6.4.2.6 Distributing Bundled Savings to Measures

DHW conservation and miscellaneous space heating conservation measures (gas model only) are represented in the regression model as a single term. This term is set to 1 if any one or more of the specified measures were installed. The regression coefficients represent the average savings for the group of measures. These savings are then distributed to the measures proportionally on the basis of the deemed savings from the DEER report. The same approach was used for both the gas and electric models.

The process for distributing the DHW package savings is as follows.

- The deemed savings for the DHW package are calculated by household using the mix of measures installed in that home, i.e., the number of showerheads installed is multiplied by the DEER savings for showerheads, etc., and the total savings for each measure summed.
- The mean value of the household savings for all homes with a DHW measure and an electric or gas water heater is determined.
- The average household savings are compared to the regression coefficient for the DHW package to calculate a realization rate. The deemed savings for each measure are adjusted by this ratio to estimate the measure savings.

The deemed savings values used for the DHW measures are listed below.

Table 6-7: Deemed Savings for DHW Measures

	Electric Savings (kWh/year)		Gas Savings (Therms/year)	
Measure	Multifamily	Single Family	Multifamily	Single Family
Faucet Aerators	75	60	3	4
Low Flow Showerheads	150	185	9	10
Pipe Wrap	75	95	5	5
Tank Wrap	200	250	12	13

Distributing savings to the space heating measures is more complicated. The following measures listed in tables 7-18 to 7-20 are aggregated in the “other space heating” variable: caulking, weatherstripping, building envelope repair, evaporative cooler covers, miscellaneous envelope measures (outlet gaskets) and furnace filters. West Hill Energy developed standardized measure categories for all of the utilities, and a number of the West Hill Energy’s measure categories are incorporated into the “building envelope repair” measure, including door replacement and repair, attic ventilation and minor envelope repair.

The deemed savings are directly from the DEER report. The DEER values are calculated by climate zone (CEC forecasting climate zones) and by house. For the most part, the selected DEER measures were specifically estimated for the low income sector. The DEER report does not include estimates for CEC forecasting climate zone 14, although a small number of sample participants have homes located in this climate zone. The savings for CEC forecasting climate zone 4 are also applied to 14, since zone 4 has the closest weather patterns based on normalized heating and cooling degree days. Table 6-8 below shows DEER measures matching up to the WHEC measure categories.

Table 6-8: Report Measure Categories and DEER Measures

WHEC Measure Category	DEER Measure(s)
Door replacement & repair	Door weatherstripping (savings from tightening doors by replacement or repair is assumed to be similar to savings from door weatherstripping)
Evaporative cooler covers	Evaporative cooler covers
Miscellaneous envelope measures	Outlet gaskets
Attic vents	Attic vents
Minor envelop repair	Combination of door and attic access weatherstripping (savings for minor envelope measures were assumed to be similar to combined weatherstripping)
Caulking	Caulking
Weatherstripping	Door weatherstripping
Furnace filters	Furnace filters are not a measure in the DEER database; from past evaluations, the savings from furnace filters are roughly similar to weatherstripping; the DEER value for weatherstripping savings was used, to be able maintain the variations among the forecasting climate zones

Developing the measure-level savings for the “other space heating measures” from the DEER estimates involves the following steps.

1. The coefficients developed from the regression analysis are used to determine the savings from the “other space heating measures” by household, i.e., the coefficient is multiplied by the normalized degree days by home.
2. These savings are averaged by CEC forecasting climate zone, giving a single value representing the mean savings for the aggregated “other space heating” measures by climate zone and by house.
3. Using the mix of measures in each climate zone, the deemed savings are calculated and averaged by household, resulting in an estimate of the deemed savings by climate zone and by house.
4. The regression-based result is compared to the deemed savings to determine the realization rate by climate zone.
5. This realization rate is applied to the deemed savings associated with each of the WHEC measure categories by climate zone.
6. The resulting estimates of savings for each measure are then applied to all participating homes and averaged by utility to obtain the values shown in the series of tables beginning with 7-17. For the “building envelope repair” category, the household savings reflect the mix of the WHEC measure categories that were installed in that home. For example, for a home with a door replacement, attic ventilation and minor home repairs, the savings for each of these measures are added together to obtain the “other space heating” savings for the home.

Since the P&P Manual uses the CEC Title 24 (building) climate zones (which are not consistent with the CEC forecasting climate zones), an additional step is needed to complete the analysis by climate zone. The data set includes both forecasting and Title 24 climate zones for each participant. The average measure savings are applied to each household with the measure by forecasting climate zone; the total savings are then aggregated by Title 24 climate zone.

6.5 Results of Diagnostics

The effects of outliers, collinearity and autocorrelation are assessed as part of the model diagnostics.

6.5.1 Outliers

Savings tend to be somewhat unstable for the SCE cooling model and the package of electric hot water measures. When the SCE cooling model is weighted for outliers, the results show lower savings for evaporative coolers and air conditioners, but higher savings for evaporative cooler maintenance, which would be likely to balance out when calculating total program savings.

The confidence intervals for the electric DHW package for all utilities are quite wide, indicating a high degree of variability. (See Table 7-12.) SDG&E’s savings for this set of measures in particular are not statistically significant. However, when the three methods of identifying and removing outliers were compared, the results were somewhat contradictory, with two of the methods resulting in lower savings and one producing substantially higher savings. For PG&E and SCE, the coefficients obtained when the outliers were removed or weighted were within the confidence intervals from the base model.

The gas model is more stable. The savings associated with the bundle of miscellaneous space heating measures seems to be somewhat susceptible to the effects of outliers, and the analysis of outliers suggests that the savings may be understated.

The savings for evaporative cooler maintenance in the PG&E model are surprisingly high, and warranted special attention. The analysis of outliers described in Section 6.3.5 was applied to this model, as well as an additional step of randomly assigning the participants with this measure to eight equally-sized groups, rotating each group out and then comparing the results. All of these analyses indicate the regression results for this measure are not affected by outliers.

Weighting for outliers tends to lead to minor variations in measure savings, and will be likely to have little effect on the total program savings, particularly considering that the unstable measures are also those less frequently installed. The loss of precision due to the inclusion of outliers is likely to be a relatively small component of the total error associated with this analysis, particularly in the context of the data collection issues.

After reviewing the results of the diagnostics, we decided to keep the outliers in the analyses without weighting. This decision was based on three considerations: (1) the inconclusive, and sometimes contradictory, results of the three methods used to assess the impacts of outliers, (2) the scope of the issues with the data collection, and (3) the small effect that adjusting for outliers would be likely to exert on the total program savings. A summary of the output from the analysis of outliers is presented in Appendix A-4.

6.5.2 Collinearity

Collinearity tends to be an issue whenever many variables are incorporated into the analysis reflecting measures installed at the same time or other effects have a high correlation with the measure installations. In this case, the effects of collinearity are the most problematic in estimating savings for homes with electric water heating who received DHW conservation measures (faucet aerators, showerheads, pipe insulation and/or tank wraps). Almost all of these homes also have electric space heating, which adds a high degree of variability to the usage patterns in these homes. The DHW savings tend to be highly variable when the electric space heating measures are also included in the model.

As discussed earlier, the model shows increased usage for all homes with electric space heating, in both the comparison and the treatment group. The pattern exists for, those homes with space heating measures and those without. These effects make it difficult to separate the savings for the DHW savings from the overall household variations. One approach is to bundle the water and space heating measure together. However, the additional use from the homes with electric space heating overwhelm the savings from the DHW measures, showing a net increase in the usage level of homes with the combined water and space heating measures. The model improved significantly when the space heating measures were removed and a variable added to capture the change in use in all homes with electric space heating.

The correlation matrices were reviewed for each of the final models. In general, SCE showed little correlation among the modeled measures, and PG&E and SDG&E showed a high degree of correlation between lighting and other measures. This result simply reflects the program implementation strategy where lighting was installed in most homes in PG&E's and SDG&E's programs.

The high estimate of savings for evaporative cooler maintenance from the PG&E cooling model was also a matter of concern and collinearity was eliminated as a factor. A review of the data set did not reveal that this measure was consistently installed in conjunction with another measure.

6.5.3 Autocorrelation

Autocorrelation is known to be an issue with time series regressions. Monthly reads at a particular home are likely to be closely related to the read in the previous month. Not too surprisingly, the Durbin-Watson test for autocorrelation results in a score of .56 for the combined utility electric base model, when the customer-specific intercepts are not included in the model. This is substantially below the desired value of 2. The presence of autocorrelation would not be expected to have an impact on the values of the coefficients, although it tends to reduce the magnitude of the standard errors. Including customer-specific intercepts in the model partially mitigates this problem and bootstrapping was used to develop the standard errors for estimating the confidence intervals.

6.5.4 Comparison of Bootstrap and Regression Results

As discussed above, bootstrapping was used to check the level of precision from the regression analysis. Our team was concerned that the autocorrelation inherent in the monthly billing data would cause confidence intervals calculated in the regression analysis to appear to be substantially smaller than is actually supported by the data. As shown in Table 6-9, the results of this comparison indicate that the standard errors calculated using the bootstrap method are consistently higher, sometimes doubling or tripling, the standard errors calculated in the regression analysis. The results from the gas model are similar. Given this result, the bootstrapping standard errors were used to calculate the confidence intervals for all of the models, as presented in Table 7-12.

Table 6-9: Comparison of Bootstrap and Regression Standard Errors

	# of House-holds	# of Units Installed	Reg[18] Coeff	Reg Standard Error	Bootstrap Standard Error	% In-crease
PG&E						
Refrigeration	5,611	5,611	685	11.2	21.0	88%
Lighting	22,197	108,695	43	2.5	4.4	76%
DHW Package	1,220	1,220	104	21.7	50.8	135%
Evap Coolr Maint (interaction)	393	393	223	11.4	23.2	103%
SCE						
Refrigeration	6,031	6,031	666	11.7	21.0	80%
Lighting	7,400	26,193	21	3.1	6.0	92%
DHW Package	297	297	261	33.7	71.1	111%
Evap Cooler Install (main)	114	114	452	138.6	204.5	48%
Evap Coolr Install (interaction)	114	114	(35)	31.2	93.6	200%
Evap Coolr Maint (interaction)	1,741	1,741	24	6.7	24.1	257%
A/C Replacement	914	914	145	13.8	43.3	215%
SDG&E						
Refrigeration	2,251	2,251	674	15.1	32.0	112%
Lighting	2,561	7,203	29	4.6	10.3	127%
DHW Package	155	155	213	41.8	146.0	249%
Gas						
DHW Package	32,195	32,195	4.0	0.62	0.80	30%
DHW Replacement	1,068	1,068	18.8	2.06	2.50	21%
Furnace Repair	1,173	1,173	(4.8)	0.28	0.79	184%
Furnace Replacement	1,899	1,899	(9.3)	0.25	0.64	154%

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[18] The value of the regression coefficient is not always equal to the annualized kWh savings for the measure, due to the inclusion of weather-dependent terms in the model.

Attic Insulation	2,940	2,940	8.0	0.10	0.37	263%
Programmable Thermostats	1,988	1,988	(1.8)	0.17	0.40	140%
Duct Sealing/Repair	1,069	1,069	(1.2)	0.25	0.61	140%
Misc. Space Heating	39,581	39,581	1.5	0.10	0.20	108%

6.6 Alternative Models

Misspecification of the model occurs when either critical variables are not included in the model or nonsignificant variables are included. Billing analysis by its nature is an imperfect science. The objective is to assess energy savings, but the measure value is overall household usage, which may be influenced by any number of factors that cannot be modeled. Consequently, the model will be misspecified to some degree, and many alternatives were considered to try to improve the results. Some of these are discussed below.

- A dummy variable reflecting program participant (0 during the pre-period and 1 during the post-period) was added; this variable reflects program effects beyond the measures installed. The results show that there probably are some program effects not captured in the measure savings, but the addition of this variable has a strong downward effect on the savings for base measures, such as lighting. This result is consistent with the installation of lighting in most homes, and indicates that it is not possible to estimate both the program effect (possibly from the energy education component) and the savings for base measures from the regression model. This result also suggests that some savings from general program effects are embedded in the base measure savings.
- P&GE’s and SCE’s databases include a field indicating whether the home had central air-conditioning. This variable was included in the regression analysis, but did not improve the results. It is clear from the analysis that both homes marked as having central air conditioning and those without it were using a significant amount of electricity for cooling in the pre-installation period. Many of these participants may have room air conditioners.
- Due to the high coincidence of electric water heating measures in homes with electric space heat, we bundled all space and water heating measures together, as discussed previously under collinearity. However, the additional use from the homes with electric space heat seems to have overwhelmed the potential savings from both the electric space and water heating measures.
- The gas model was run with and without the care/post variable. When the care/post variable is removed, the DHW savings increase from 4 therms per year to almost 8 therms per year. This result could be an indication that the efficiency improvements for DHW are showing up in the care/post variable, suggesting that the savings for gas water heating conservation measures are understated in this study.

6.7 Simple Pre/Post Analysis: Selection of the Comparison Group

The comparison group was initially selected for the simple pre/post analysis and then also included in both the electric and gas regression models. The comparison group consists of

2003 LIEE participants, in the period prior to their participation in the program.

The pre/post analysis was conducted as a check on overall household savings levels. A major factor influencing the results of the simple pre/post analysis is the validity of the specified control. An analysis of this type must have comparison and treatment groups that are closely matched because the comparison group is assumed to remove all extraneous factors from the equation. Savings are not explicitly normalized for weather, and the comparison group is assumed to account for all non-program effects, including weather effects.

The two groups were matched according to the level of pre-installation usage, utility, and housing type as the major indicators that the groups are similar in characteristics. Using this process, the level of pre-installation usage generally matches within 5%, and is often less than 3%.

Time period is the other key variable. To account for weather effects properly, the pre and post periods for the two groups must correspond. The time period selection is tied to the usage level to address the weather-dependent consumption of treatment and comparison group members in the higher usage categories.

Given these considerations, we decided to sample from the potential comparison group members to obtain the closest possible match. The selection of the comparison group sample was done in two stages:

- In the first step, the treatment group was sorted by utility, housing type and usage level and the comparison group was selected from these categories in the same proportions as found in the treatment group.
- Potential comparison group members were further screened to ensure that the treatment and comparison groups were reasonably well distributed by usage level and time period.

Additional details on the specifics of this analysis are included in Appendix A-3.

6.8 Premises v Accounts

The primary analysis was conducted at the account level, and the savings estimates presented in this report are based on the account-level sample. The account is associated with the participant who is living at the home at the time of the site visit. This approach has two advantages: (1) it reduces the variability in energy usage associated with a change in tenancy, and (2) it allows for the possibility that the analysis may pick up additional program effects above the actual measure installations, such as the impact of the energy education component of the program. The major disadvantage is that the attrition is higher and the sample size somewhat smaller.

The premise is the actual dwelling, regardless of the resident at any given time. Consequently, it is entirely possible, and quite common, for a number of changes in occupancy to occur within the three-year analysis period. New residents are likely to have different usage patterns, adding a higher degree of variation to the savings estimates, and any behavioral changes made by the participants in response to the program will be lost. However, billing data covering the entire analysis period is more available at the premise level and this approach permits a larger sample size.

To investigate the differences between the premise-level and account-level savings, the group of participants with sufficient billing data at the premise-level, but eliminated at the account-level, are analyzed. In the electric base model, the household savings for this group are about 10% lower than the household savings for the account level sample, falling within the 95% confidence interval for the account-level sample.

6.9 Comparison to Previous Evaluations

Every evaluation requires professional judgment at every step. This section compares and contrasts the modeling decisions made in our analysis to the previous two impact evaluations conducted by KEMA-Xenergy. The similarities are listed in Table 6-10 and the key differences summarized in Table 6-11.

Table 6-10: Modeling Similarities between PY2002 and Previous Evaluations

Modeling Decisions	• Fixed effects regression model with customer-specific intercepts • Sample included all participants with sufficient billing history • Water and some space heating measures were aggregated and represented by a single variable in the regression model

6.9.1 Regression Models

Overall, our regression models are similar in some critical respects. A fixed effects regression model was chosen for all three evaluations. Customer-specific intercepts were used in all three analyses to account for house-specific characteristics. As KEMA-Xenergy did, we opted for the increased power of including all participants with sufficient billing history into the model, although, unlike KEMA-Xenergy, we developed separate models for the cooling measures and by utility for the base measures.

The request to produce detailed savings at the measure level combined with the conclusion that billing analysis is the only viable option created challenges equally for the PY 2002 evaluation and the earlier ones. In both the 2001 and the current 2002 evaluations, the hot water and space heating measures are aggregated into a limited set of variables in the regression model and the savings for the aggregate water and space heating variables are distributed to the measures proportionally using deemed savings from the DEER report.

While the general approach to distribute savings to measures by deemed savings is similar, the specific methods differ. KEMA-Xenergy used deemed savings estimates to weight the relative savings of the measures within the regression model. The coefficients then represent the realization rates to be applied to the deemed savings. For example, the “weatherization” package includes measures such as weatherstripping, programmable thermostats, and attic insulation. The deemed savings are the same for every home, regardless of house-specific conditions that may affect savings. In the case of weatherization measures, attic insulation has far more weight than the others and probably dominates the determination of the coefficient on which the savings are based. Accordingly, the estimates of savings for the smaller measures, such as caulking and weatherstripping, are more likely to reflect the relationship between deemed and actual savings for attic insulation rather than a significant relationship between changes in usage and the installation of weatherstripping.

In the gas model, we created separate terms for measures with high deemed savings, such as attic insulation, programmable thermostats and duct repair, and bundled those measures with savings of a more similar level. Also, we did not weight within the variable, but rather used dummy variables set to one if any of the bundled measures were installed in the home.

6.9.2 Fuel Types

Our team and KEMA-Xenergy both wrestled with how to address the uncertainty surrounding the presence of cooling equipment and the fuel types for space and water heating; although our solutions are somewhat different. Generally, KEMA-Xenergy assigned fuel types and air conditioning equipment to homes based on the usage levels and patterns, although in a few specific cases they used the data provided by the utilities. They established criteria to define homes with electric space and water heating and with air conditioning. For example, homes using over 800 kWh per summer month are assumed to have air conditioning.

Although initially preferring to avoid the problem by estimating savings for all participants regardless of fuel type, our team ultimately decided that fuel type designators are critical to obtaining reasonable results from the model, and we opted to use the designators provided by the utilities from their program or customer database. We continue to be concerned that the Xenergy-style approach requires one to establish criteria that are high enough to eliminate homes without the end use, but will also eliminate homes of participants with lower usage that may indeed have the heating equipment. Thus, this process may introduce systematic error, by estimating savings only for larger users who are likely to be reaping the benefits of higher savings. The utility-supplied fuel-type designators are not available for some participants and this missing information introduces random error to the model. There is no evidence that using the utility designators introduces any systematic error, however.

6.9.3 Precision

The confidence intervals as presented in the 2001 impact evaluation conducted by KEMA-Xenergy are based on regression results. As discussed previously, our bootstrapping analysis suggests that since the number of observations greatly exceeds the number of homes in the sample and the monthly reads are autocorrelated, the regression-based standard errors are substantially understated.

6.10 References

Please see the references listed at the end of Chapter 5.

Table 6-11: Comparison of PY2002 Evaluation Methods to Previous Evaluations

	PY 2002 Evaluation	PY 2000 & 2001 Evaluations	Impact
External factors	• The volatile period of the 2001 California Energy Crisis was the pre-installation period for this analysis	• The analysis periods for these evaluations also included 2001 and 2002; the period of depressed use falls within the post-installation period for these evaluations	• Use during 2001 and 2002 was depressed (possibly due to voluntary conservation), affecting our ability to estimate savings for some measures in PY2002, particularly weather-dependent measures • Trends in use during this period could also have affected the PY2000 and 2001 evaluations
Fuel Types for Major End Uses	• Determined by utility designators	• In some cases, utility designators were used; in others, the presence of major end uses was determine by the billing history in each home	• Both methods introduce random error to the model • Defining the presence of major end uses by consumption patterns may also introduce systematic error
Weighting of Measures within Combined Variables	• Dummy variables used for combined water and space heating variables; coefficients represent savings • Individual variables included for measures with higher deemed savings	• Aggregated variables reflect contribution of deemed savings for each measure; coefficient represents the realization rate • All envelope measures were aggregated, regardless of the magnitude of the deemed savings	• Using the PY2000 and 2001 methodology, the results are likely to reflect the realization rate for the measure(s) with the largest deemed savings
Precision	• Confidence intervals calculated both from regression analysis and by bootstrapping	• Confidence intervals calculated from regression results	• Standard errors from regression output do not account for autocorrelation in the model; bootstrapping suggests that standard errors from the regression model are understated
Equipment Replace-ment	• Savings estimated for all participants with the measures, since it was not possible to identify the homes with functioning equipment before the new measure was installed	• Savings estimated only for participants with consumption patterns indicating a drop in use during the post period, suggesting that the original equipment was in use prior to the installation	• PY 2002 evaluation indicates increased use for many of these measures, possibly due to homes with inoperable equipment prior to the installation; program changes may also have some effect • The methodology used in the PY 2000 & 2001 resulted in estimated savings for these measures

7 Results

This section presents the results of our PY2002 impact analyses. The first part provides a brief overview. In the second section, we summarize the program activity during PY2002, such as measure counts for all participants and household savings from the current evaluation as compared to the previous two evaluations. The third section describes the selection of the sample and the reasons for attrition. The results of the regression are presented next, along with the precision of the estimated coefficients, and a discussion of the issues identified through the regression analysis. The final section provides the summary tables of program savings by utility, measure and fuel type.

7.1 Overview

As anticipated, the household savings and savings from larger measures are reasonably robust, but the savings for smaller measures were difficult to estimate. The results from the regression and simple pre/post analyses are fairly consistent at the household level, and for lighting and refrigeration, the two measures that make the largest contribution to total electric savings. A comparison of the results of the simple pre/post and regression results for the account-level sample is given in Table 7-1 below.[19]

Table 7-1: Comparison of Household Savings and Selected Measures

	Regression	Simple Pre/Post
Household Savings (annual kWh)	323	355
Refrigerators (annual kWh)	701	702
Lighting (annual kWh)	26	34
Gas Household Savings (annual therms)	7.9	4.1

Variations between the regression and simple pre/post results are likely to be caused by the difference in the structure of the analyses. The regression analysis has a much greater capability of accounting for weather and other non-program effects than the simple pre/post.

Table 7-2 compares the household savings from the 2000, 2001 and 2002 evaluations.[20] For all three years, the household savings are calculated based on the total number of

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[19] These numbers are for the participants included in the sample only. They will vary from the total program savings due to variations in the mix of measures installed.

[20] For 2002, the count of total participants is taken from the utilities' 2002 Annual Earnings Assessment Proceeding (AEAP) reports, submitted to the PUC. The source of the household savings for PY2000 and PY2001 are the previous evaluations conducted by KEMA-Xenergy.

participants, regardless of the fuel type saved. For SDG&E and PG&E, some participants received only gas measures, some only electric measures, and others installed a combination of gas and electric measures. Thus, some of the variability for these two utilities could relate to changes in the composition of the participants and mix of measures.

Table 7-2: Comparison of Household Savings, PY2000 to PY2003

	Average Annual Energy Consumption[21]	Median Annual Energy Consumption	PY 2002 Evaluation	PY 2001 Evaluation	PY 2000 Evaluation
Electric Savings (kWh)					
Combined Utilities[22]	5,074	4,143	366	213	175
PG&E	5,435	4,482	399	236	240
SCE	4,519	3,738	286	203	153
SDG&E	4,198	3,468	370	215	89
Gas Savings (Therms)					
Combined Utilities	408	343	8	18	24
PG&E	459	264	9	18	28
SDG&E	348	319	4	13	13
SoCalGas	385	327	8	20	26

Total program savings by utility are summarized in Table 7-3 below.

Table 7-3: PY 2002 Total Program Savings

	# of Participants	Annual MWh	Annual Therms
PG&E	70,683	28,212	606,592
SCE	29,685	8,495	
SDG&E	14,089	5,216	57,576
SoCalGas	39,464		322,721
Totals		41,923	986,899

The gas household savings in PY2002 are substantially lower than shown in previous evaluations. The unit savings per measure tend to be smaller than those estimated in the earlier studies, and no savings are found for furnace replacements or repairs for the 2002 participants. This result may be partially due to the external conditions, although differences in modeling strategies may also have an impact.

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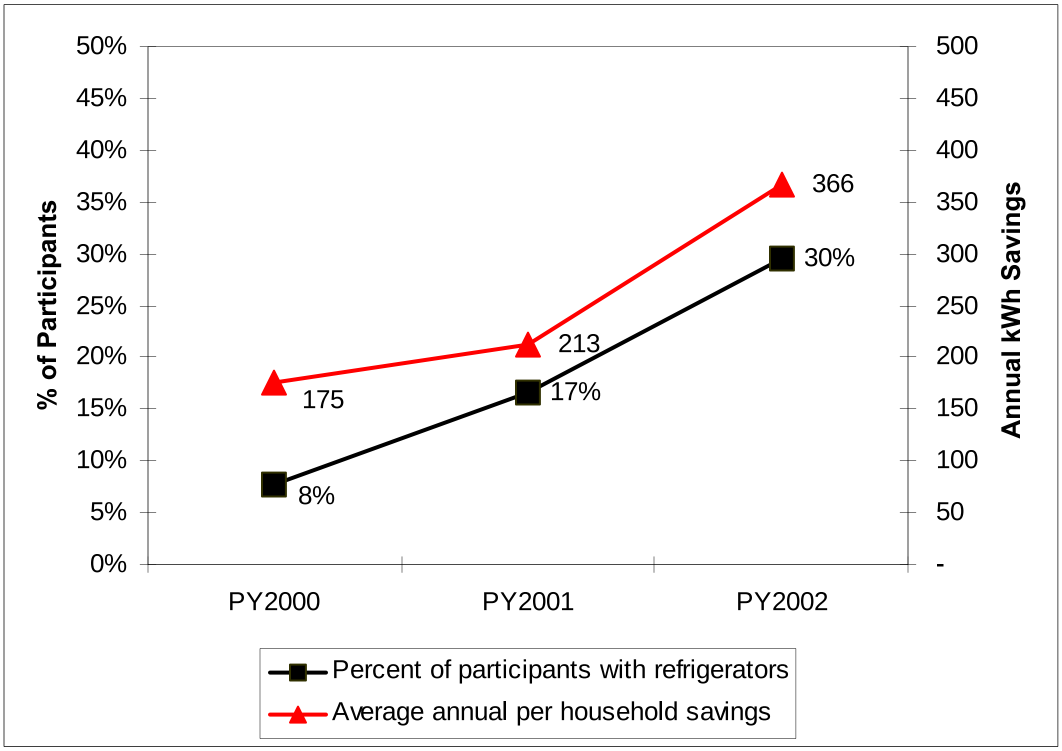
[21] This column reflects the average annualized kWh consumption for 2002 participants who were included in the account sample.

[22] Combined utility consumption average and median were calculated from the combined data set used for the regression analyses. Household savings were derived by summing the savings across all the utilities and dividing by the total number of participants.

Electric savings increase steadily from PY2000 through 2002. Table 7-2 shows the annual estimated household savings for the 2000, 2001 and the current 2002 evaluations, along with the annual kWh consumption for the sample of 2002 program participants during the pre-installation period. This trend appears to be driven primarily by the increase in the penetration of efficient refrigerators in the program, as illustrated in Figure 7-1.

Figure 7-1: Annual Household Savings and Penetration of Efficient Refrigerators



Overall, the electric regression model shows a trend of lower energy use during the first half of 2001 and then increasing throughout the period. Although it is beyond the scope of this study to investigate the reasons for this variation in energy use, it appears that consumption was depressed during the pre-period, coinciding with the California Energy Crisis and specific efforts by utilities and regulators to encourage lower demand for electricity.

A possibly related finding is that the model shows no savings from electric space heating measures, and gas savings are substantially lower than found in previous evaluations. Weather-dependent energy use may be discretionary in some areas, and behavioral changes occurring during the Energy Crisis could be one factor hampering our ability to identify savings for these measures from the billing analysis. The regression model shows an increase in electric space heating use across the board between the pre- and post-installation periods. However, these results must also be considered in the context of the data issues associated with this program, including the uncertainty surrounding the fuel types used for space heating.

A number of measures show a net increase in energy use rather than a decrease. These measures include furnace repair and replacements, evaporative coolers and air conditioners. This effect is likely to be related to the program implementation strategy of installing all feasible measures, allowing for the possibility that new heating and cooling equipment may be installed in homes with previously inoperable systems. (See Chapter 8 for a discussion of issues by measure.)

Household savings are reasonably stable, but the reliability of the measure-level estimates varies. The results for refrigerators are robust and are similar to the savings estimates in previous evaluations. Lighting savings are more variable, but still statistically significant. The savings for cooling, DHW conservation and gas space heating measures should be considered less reliable due to issues with the program data, the small magnitude of the savings and instability in the models.

7.2 Program Activity

The next four tables show the measures installed by housing type for the participating utilities. In total, over 150,000 homes were served, with more than 30,000 receiving efficient refrigerators and more than 15,000 homes receiving weatherization services in PY2002.

Table 7-4: PG&E Summary of Program Activity by Household

Measure Categories	Multi-family	Mobile Homes	Single Family	Unknown	Total
Refrigerators	1,096	761	4,644	11,737	18,238
Lighting Products (CFL's)	6,586	2,099	20,158	34,697	63,540
Water Heating	5,572	1,709	17,304	12,353	36,938
Envelope	5,005	1,527	14,937	11,795	33,264
Heating System	1,959	1,341	8,568	6,727	18,595
Cooling Measures	1,783	512	4,667	8,323	15,285
Total Program Participants[23]					70,683
Average # of End Uses per Household					2.6

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[23] The number of program participants in this series of tables is taken from the utilities' AEAP reports and reflects the number of households. The total by measure category is based on the number of unique accounts with the measure.

Table 7-5: SCE Summary of Program Activity by Household

Measure Categories	Multi-family	Mobile Homes	Single Family	Unknown	Total
Refrigerators	5,070	73	4,536	102	9,781
Lighting Products (CFL's)	8,525	254	6,623	116	15,518
Water Heating	1,377	11	317	7	1,712
Envelope	1,469	11	408	8	1,896
Heating System	625	3	9	9	646
Cooling Measures	2,610	303	2,202	117	5,232
Total Program Participants					29,685
Average # of End Uses per Household					1.2

Table 7-6: SoCalGas Summary of Program Activity by Household

Measure Categories	Multi-family	Mobile Homes	Single Family	Unknown	Total
Water Heating	13,022	582	14,990	1	28,595
Envelope	16,689	762	20,005	1	37,457
Heating System	42	158	3,164	0	3,364
Total Program Participants					39,464
Average # of End Uses per Household					1.8

Table 7-7: SDG&E Summary of Program Activity by Household

Measure Categories	Multi-Family	Mobile Homes	Single Family	Unknown	Total
Refrigerators	3,674	310	1,802	1	5,787
Lighting Products (CFL's)	3,869	425	4,811	0	9,105
Water Heating	3,114	410	3,040	1	6,565
Envelope	3,335	374	3,033	1	6,743
Heating System	119	406	540	0	1,065
Cooling Measures	306	164	36	0	506
Total Program Participants					14,089
Average # of End Uses per Household					1.3

7.3 Attrition

The simple pre/post and regression analyses were conducted at the account level. These analyses required that the billing history be correctly matched and cover a sufficient period of time to reflect pre- and post-installation use. Premises and accounts were only

removed for cause, resulting in a sample frame that included as many participants as possible. The bulk of the attrition of participants occurred at the premise level.
The same process was used to identify the sample for both the electric and gas models. The total population was defined as those participants with measures expected to save the specified fuel, e.g., 118,278 participants received electric measures, representing the entire potential sample for use in the electric model. Many eliminated participants failed to meet multiple criteria, but are assigned to a category based on the order of the steps in the data cleaning process. The reasons for the attrition are discussed below:

- Master-metered or C&I accounts: these accounts include billing history for numerous units; since we are unable to determine the total number of units on the meter or the percent of the residences that received treatment, it is not possible to tease out program impacts from the aggregate billing history.
- No utility account identified: we are unable to locate these accounts in the consumption records provided by the utilities or there was no account identifier associated with the participant information.
- Insufficient pre/post billing history: these participants did not have sufficient billing history to perform the analysis. There are substantial gaps in service at many of the premises served, generally coincident with a turn over in account, resulting in the elimination of a greater percentage of participants at the premise-level than had been anticipated.
- Beyond data range/other: some installations occurred outside of the 2002 calendar year, and these participants are not included in the analysis due to the difficulties of adjusting the analysis parameters to accommodate the wide range of dates. Participants who were found in both the treatment group (PY2002 participants) and comparison group (PY2003 participants) were also removed.

Table 7-8 below shows the various reasons for removing premises from the analysis for the three electric utilities (PG&E, SDG&E and SCE.) As can be seen, the original population of 118,278 premises is reduced to 66,789 premises with available data for the combined electric model.

Table 7-8: Attrition from the Electric Model by Utility

	Combined Utilities	PG&E	SCE	SDG&E
Total Premises with Electric Measures	118,309	73,082	29,072	16,155
Reason for Elimination				
Master-metered/C&I Rates	15,516	9,291	1,701	4,524
No History	25,913	24,186	1,431	296
Insufficient pre/post	3,964	1,779	1,837	348
Out of date range/other	6,066	840	1,548	3,678
Premise Sample Size	66,847	36,986	22,552	7,309
Percent of Total	57%	51%	78%	45%
Insufficient account pre/post	18,975	8,277	7,479	3,219
Account Sample Size	47,872	28,709	15,073	4,090
Percent of Available Accounts	72%	78%	67%	56%

Table 7-8 indicates that over half of the entire population is available for the premise level model. The largest single cause for premise attrition in PY2002 was the upgrading of the customer information system at PG&E that made it difficult to match participants to account numbers. It is unlikely that this will impact future evaluations to such a degree. The next largest factor is the removal of master-metered premises that are unsuitable for this type of analysis.

As would be expected, the rate of attrition is lower for premises than accounts. All of the eliminated premises are unavailable for the account model. The additional attrition at the account level is almost entirely due to account turn over, resulting in less than the required pre and post consumption needed for the billing analyses. The bottom section of Table 7-8 shows the level of attrition occurring at the account level. The final sample has less than half of the total eligible sites.

Table 7-9 shows the same information for the gas model. Overall, attrition from the gas model was significantly lower than from the electric model. These differences can be attributed to the lower incidence of master metered premises and fewer participants lacking sufficient consumption history.

Table 7-9: Attrition from the Gas Model by Utility

	Combined Utilities	PG&E	SCG	SDGE
Total Premises with Gas Measures	71,050	24,594	39,179	7,277
Reason for Elimination				
Master-metered/C&I Rates	1,857	493	1,026	338
No History	11	4	1	6
Insufficient pre/post	10,102	3,213	4,084	2,805
Out of date range/other	5,783	1,663	3,644	476
Premise Sample Size	53,297	19,221	30,424	3,652
Percent of Total	75%	78%	78%	50%
Insufficient Account Pre/post	9,637	4,177	4,498	962
Account Sample Size	43,660	15,044	25,926	2,690
Percent of Available Premises	82%	78%	85%	74%

7.3.1 Other Demographics

The resulting sample was also compared to the original population with respect to housing type, senior citizens and renters/homeowners. Other demographics, such as income level, were either not readily available or not considered reliable.

A high proportion of mobile homes were eliminated (over 80% in the electric model and about 65% in the gas model) due to the prevalence of master-metered mobile homes parks. This practice is consistent across all the four participating utilities, and, consequently, the resulting sample is not adequate for the purposes of estimating savings for measures installed in mobile homes as compared to the other housing types. Multifamily residences were somewhat less represented in the sample than in the total population. Tables showing the attrition by house types are provided in Appendix A-5.

The percentage of seniors in the original population and in the account sample is similar, at 32% and 35% respectively for the electric model, and 29% and 25% for the gas model. The proportion of homeowners in the sample follows a similar pattern. Owners account for 38% of the original population and are represented at 45% in the account sample for the electric model, and 45% and 56% for the gas model, respectively.[24] Given the relative similarity of the sample to the total population for these demographic factors, the models are not weighted.

This analysis suggests that the participants included in the sample are similar to the total population of LIEE participants in these two respects. It is possible that other, unknown differences between the two groups could exist and may have an impact on the results.

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[24] In both of the above cases, it is assumed that the portion of the population with missing data was equally divided between the two groups.

7.4 Regression Results

Table 7-10 shows the results and precision of the regression results. Refrigerator savings are reasonably precise and consistent across utilities. Lighting is more variable, but still statistically significant. Savings from DHW, space heating and cooling measures are less reliable.

As noted in Chapter 6, Section 6.5.4, the bootstrapping standard errors are substantially larger than the results of the regression analysis would indicate. Some measures (marked with an asterisk) are statistically significant when the regression standard errors are used, but applying the bootstrapping standard errors effectively negates that result. Diagnostics indicate that other issues, such as outliers and collinearity, also affect these measures (DHW package (SDG&E), and evaporative cooler installations and maintenance (SCE)).

Table 7-10: Regression Results and Precision Table

	# of Households in Sample	Savings per unit	95% Confidence Limits	
			Bootstrap Lower	Bootstrap Upper
PG&E Electric				
Refrigeration	5,611	685	644	726
Lighting	22,197	43	34	52
DHW Package	1,220	104	4	204
Evap Cooler Maintenance	393	511	407	615
SCE				
Refrigeration	6,031	666	625	707
Lighting	7,400	21	9	33
DHW Package	297	261	122	400
Evap Cooler *	114	414	(36)	863
Evap Cooler Maintenance *	1,741	51	(45)	147
A/C Replacement	914	107	44	170
SDG&E Electric				
Refrigeration	2,251	674	611	737
Lighting	2,561	29	9	49
DHW Package *	155	213	(73)	499
Gas Model				
DHW Replacement	1,068	18.8	13.9	23.7
DHW Package	32,195	4.0	2.4	5.6
Furnace Replacement	1,899	(33.8)	(38.4)	(29.3)
Furnace Repair	1,173	(18.4)	(25.1)	(11.6)
Insulation	2,940	41.8	38.0	45.6
Space Heat Conservation	39,581	6.6	4.9	8.3
Programmable Thermostats	1,988	(10.3)	(15.0)	(5.7)
Duct Sealing	1,069	(6.4)	(12.6)	(0.2)
* indicates results are not statistically significant at the 95% confidence level.				

In the remainder of this section, we discuss some of the issues arising from the regression analysis, including

- general participation effects
- overall trends in energy use
- savings from conservation measures targeted to electrically heated homes
- variability in the electric water heating measures and cooling measures
- measures showing an increase in use, and
- energy savings from the gas model

Following this discussion, the tables of program savings for each utility by fuel type are presented.

7.4.1 Participation Effects

The models indicate that there may be savings associated with participating in the program but not tied to a specific measure. However, further analysis shows it is not possible to distinguish between savings from the base measures and general "participation effects." The impacts of the participation effects are embedded in the savings for the base measures, and thus incorporated into the program savings. In particular, it appears that PG&E's relatively high savings per lighting product reflect this general participation effect.

Numerous factors could be contributing to the non-measure specific savings, including savings from measures not explicitly included in the model, behavioral changes associated with the energy education component of the program and/or savings from homes with missing or incorrect fuel type designators. An example of the latter is a home where a low flow showerhead was installed but the utility fuel type marker is blank. If this home has electric or gas water heating, the savings would not be counted among the measures explicitly defined in any of the models.

The participation effect was investigated by adding a term to the base models, set to 0 in the pre period and 1 in the post period. Table 7-11 below compares the results of the base models with and without the participation effect, for each utility.

Table 7-11: Comparison of Participation Effects by Utility

	PGE		SCE		SDGE	
	Annual Savings (kWh)	Annual Savings (kWh)	Annual Savings (kWh)	Annual Savings (kWh)	Annual Savings (kWh)	Annual Savings (kWh)
Participation Effect		**148**		**108**		**-6**
Refrigerators	685	671	666	612	671	675
Lighting	43	19	21	7	29	29
DHW Package	104	104	261	254	213	213
R-squared	0.794	0.794	0.776	0.776	0.850	0.850

In reviewing the results of this analysis, it is important to remember that either lighting and/or refrigeration measures are installed in most homes, making it difficult to separate the savings due to general participation effects from the savings associated with these base measures. In the regression sample, 98% of PG&E participants in the base model installed lighting, 60% for SCE and 65% for SDG&E. The penetration of refrigerators is 25%, 56% and 49% for PG&E, SCE and SDG&E, respectively.

In the SDG&E model, the program effect term is not statistically significant and has very little impact on the savings for the base measures. PG&E and SCE both show substantial program effects, but a resulting decrease in the savings associated with lighting and refrigeration. In PG&E's territory, lighting savings drop from 43 kWh per product to 19 kWh when the general program effect is added to the model.

7.4.2 Overall Trend in Energy Use

While the regression analysis is not designed to assess overall trends in energy use, the results suggest such a trend was present over the analysis period. The monthly dummy variables in the electric model represent the variation in usage that is not related to the explanatory variables in the model, and would be expected to vary randomly or reflect seasonal variations beyond those associated with the weather-dependent terms. However, a pattern emerges from these variables, showing a dip in usage during 2001, with a rebound in 2002 that continues through 2003. A graph of this trend in presented in Chapter 9.

Monthly dummy variables were not included in the gas model, due to the tendency of these terms to pick up seasonal variations that affect savings. Consequently, it was not possible to conduct the same analysis for the gas sample. Instead, dummy variables were added for the years of 2001, 2002 and 2003. The coefficients on these variables show depressed usage in 2001, and relatively flat usage in 2002 and 2003.

This pattern of depressed usage in 2001 (our pre-installation period) and the subsequent rebound hinders our ability to identify program savings through a billing analysis. While it is beyond the scope of this analysis to research the reasons for these variations in usage among the LIEE participants, these patterns are consistent with those observed during the California Energy Crisis. This topic is explored more fully in Chapter 9, Discussion.

7.4.3 Electric Space Heating Measures

In the electric model, no savings were found for electric space heating measures in the utility or the combined utility models. Initially, we included two terms in the regression: attic insulation and the remaining space heating measures bundled into one variable. These terms consistently showed an increase in use associated with these measures.

These variables were removed and a single term added to capture the difference in heating usage for all electrically heated homes (with or without measures installed) between the pre and post periods. This step showed a clear upward trend in usage, i.e., that participants used proportionally more electricity per degree day in the post period than prior to the installation. This pattern of increased usage was found in models with and without the comparison group.

The weather-adjusted increase in usage indicates that LIEE participants used proportionally more electricity to heat their homes as the temperatures dropped. The regression model does not explain the reasons for this change, but this pattern is consistent with lower thermostat settings in the pre-period and higher settings in the post period. This trend would tend to obscure any savings from space heating-related conservation measures.

7.4.4 Electric DHW package

For all three utilities, the savings from the DHW measure tend to be unstable, as may be expected due to the uncertainty in identifying homes with electric hot water, the high incidence of homes that have both electric water heating measures and electric space heating, the modest savings expected from these measures and the relatively small number of homes marked as having electric hot water and DHW measures (SCE and SDG&E). In the final sample, 100% of SCE’s participants with electric water heating measures lived in homes with electric space heat, 87% for SDG&E and 80% for PG&E. Homes with electric space heating tend to have larger and much more variable usage.

Also, as found in other parts of the analysis, participants in electrically heated homes, on average, used more energy for heating in the post than the pre period, and this higher use in the post period may obscure some of the impact of the DHW conservation measures. Outliers also had an impact on the DHW savings estimates, as described in Chapter 6, Section 6.5.1. This variability is reflected in the wide confidence intervals for the package of DHW measures.

7.4.5 Cooling Model

The SCE cooling model also suffers from instability. The savings from both the evaporative cooler installations and maintenance are no longer statistically significant when the standard errors derived from the bootstrapping technique are applied, highlighting the wide variations from household to household. The lack of knowledge regarding the pre-installation conditions could be contributing to this result. (See Chapter 6, Section 6.5.1 for a discussion of effect of outliers on this model.)

The PG&E cooling model, in contrast, appears to be more reliable, although the savings for evaporative cooler maintenance seem unusually high (512 kWh per year for single family homes.) Although special efforts were expended, diagnostics did not uncover underlying issues with this model.

7.4.6 Measures with Higher Energy Use

The gas and electric models show higher usage associated with some measures, including furnace replacement and repair, air conditioner replacement, evaporative coolers, programmable thermostats, and duct repair. For the equipment replacement measures, this result is not unexpected. We were unable to identify participants with inoperable systems prior to the installation, and the increased use in these homes, on average, could be overwhelming the savings. Behavioral changes (possibly in reaction to the Energy Crisis), such as variations in thermostat settings between the pre- and post-installation periods, could also be contributing to the inability to identify savings from these measures.

Savings from programmable thermostats are highly sensitive to behavioral patterns. (See Chapter 8.) The difficulty in identifying savings from duct repair and sealing could be associated with the small magnitude of the savings, or external factors affecting consumption during the analysis period.

The average net increase in consumption for these measures is likely to reflect increased comfort for participants (i.e., non-energy benefits), and does not in any way affect the energy savings from the other measures. Consequently, these “negative savings” were not included in the summary of program savings. The estimated aggregate increase in use from these measures is quantified in Tables 7-19 to 7-22.

7.4.7 Gas Model

The gas model shows very modest savings on a per unit and total program basis in comparison to previous evaluations. This result could be related to external factors, as explored in Chapter 9, as well as to modeling decisions. Table 7-12 shows the difference in unit savings for some of the major gas measures for PG&E from the three recent evaluations. This table shows the variability in measure-level savings from one year to another. While the per unit estimates in PY2002 are lower for many measures, one item that stands out is the substantial savings for furnace replacements estimated in the 2000 and 2001 impact evaluations. We suspect that a significant component of this difference may be related to modeling decisions.[25]

The savings for the package of water heating measures are also substantially smaller than indicated by previous evaluations. As discussed in the section on alternative models (Chapter 6, Section 6.6), these savings show a high degree of variability depending on the mix of variables included in the model.

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[25] In the 2000 evaluation, homes were identified as having a functional furnace in the pre period on the basis of their consumption history, i.e., a jump in gas usage in the post period was assumed to indicate that the furnace was inoperable prior to the installation. Savings were then estimated only for the homes designated as having a working furnace during the pre period. In our analysis, we did not distinguish between homes based on the condition of the furnace in the pre-period due to the absence of a reliable method to identify homes with inoperable heating systems in the pre period.

Table 7-12: Comparison of PG&E Gas Savings from 2000 to 2002

		PY2002 Unit Savings (Therms)	PY2001 Unit Savings (Therms)	PY2000 Unit Savings (Therms)
Water Heating				
Aerators	Multifamily	0.6	2.6	0.9
	Single Family	0.8	3.6	1.4
Showerheads	Multifamily	1.8	7.2	6.1
	Single Family	2.0	8.2	9.1
Tank Wraps	Multifamily	2.4	9.2	4.9
	Single Family	2.6	11.3	7.3
DHW Replacement	Multifamily	18.8	9.5	N/A
	Single Family	18.8	19.0	N/A
Space Heating Measures				
Attic Insulation	Multifamily	19.9	34.3	18.7
	Single Family	48.1	41.5	34.2
Caulking	Multifamily	0.8	1.4	1.6
	Single Family	0.9	5.2	3.3
Weatherstripping	Multifamily	1.7	2.3	1.6
	Single Family	3.1	3.9	3.3
Envelope Repair	Multifamily	2.9	3.7	4.6
	Single Family	5.8	8.2	8.8
Evap Clr Cover	Multifamily	0.4	0.9	4.0
	Single Family	0.7	3.3	4.6
Furnace Filter	Multifamily	1.7	1.4	2.3
	Single Family	3.0	3.8	4.7
Furnace Replacement	Multifamily	Higher use	60.1	147.2
	Single Family	Higher use	61.5	147.2

7.5 Program Savings by Utility and Fuel Type

In the following tables, unit savings are estimated on a per item basis for refrigerators, lighting, aerators and showerheads. For all other measures, unit savings reflect the estimated savings per dwelling. For master-metered mobile home parks and multifamily buildings, a utility account may include multiple dwelling units, and the number of accounts may be lower than the total number of dwelling units served.

Table 7-13: PGE Electric Measure and Program Savings

		Measure Counts		Unit Savings		Total Program Savings		
		# of Accounts	# of Items Installed	Heating & Other (kWh)	Cooling (kWh)	Heating & Other (MWh)	Cooling (MWh)	Total (MWh)
Non-Weather Sensitive Measures								
Refrigerators	Multifamily	1,801	1,832	685		1,255		1,255
	Mobile Homes	1,251	2,106	685		1,443		1,443
	Single Family	15,186	15,204	685		10,415		10,415
Lighting (CFL's)	Multifamily	10,182	57,557	43		2,475		2,475
	Mobile Homes	3,245	28,446	43		1,223		1,223
	Single Family	50,113	249,203	43		10,716		10,716
Water Heating								
Aerators	Multifamily	1,428	2,791	18		51		51
	Mobile Homes	255	669	15		10		10
	Single Family	1,740	3,617	15		53		53
Showerheads	Multifamily	1,169	1,319	37		48		48
	Mobile Homes	192	280	45		13		13
	Single Family	1,409	1,725	45		78		78
Pipe Wrap	Multifamily	246	246	18		4		4
	Mobile Homes	80	80	23		2		2
	Single Family	673	673	23		16		16
Tank Wraps	Multifamily	94	94	49		5		5
	Mobile Homes	37	37	61		2		2
	Single Family	322	322	61		20		20
Cooling Measures								
Evap Cooler Maint	Multifamily	20	20		301		6	6
	Mobile Homes	69	69		376		26	26
	Single Family	707	707		500		354	354
Program Totals[26]		70,683				27,826	385	28,212

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[26] Number of accounts will not sum to the program total, since some households received more than one measure.

Table 7-14: SCE Electric Measure and Program Savings

		Measure Counts		Unit Savings		Total Program Savings		
		# of Accounts	# of Items Installed	Heating & Other (kWh)	Cooling (kWh)	Heating & Other (MWh)	Cooling (MWh)	Total (MWh)
Non-Weather Sensitive Measures								
Refrigerators	Multifamily	5,123	5,141	666		3,424		3,424
	Mobile Homes	74	74	666		49		49
	Single Family	4,584	4,605	666		3,067		3,067
Lighting(CFL's)	Multifamily	8,589	31,179	21		655		655
	Mobile Homes	256	1,069	21		22		22
	Single Family	6,673	25,533	21		536		536
Water Heating								
Aerators	Multifamily	299	644	56		36		36
	Mobile Homes	11	32	44		1		1
	Single Family	76	251	44		11		11
Showerheads	Multifamily	477	587	111		65		65
	Mobile Homes	10	15	137		2		2
	Single Family	105	160	137		22		22
Pipe Wrap	Multifamily	122	122	56		7		7
	Mobile Homes	0	0	70		0		0
	Single Family	25	25	70		2		2
Tank Wraps	Multifamily	106	106	148		16		16
	Mobile Homes	0	0	185		0		0
	Single Family	17	17	185		3		3
Cooling Measures								
Evap Coolers	Multifamily	48	48		370		18	18
	Mobile Homes	14	14		535		7	7
	Single Family	207	207		514		106	106
Evap Cooler Maint	Multifamily	470	470		39		18	18
	Mobile Homes	250	250		86		22	22
	Single Family	1,865	1,865		48		89	89
AC Replacement	Multifamily	2,139	2,139		128		274	274
	Mobile Homes	50	50		245		12	12
	Single Family	108	108		270		29	29
Program Totals		29,685				7,919	577	8,495

Table 7-15: SDG&E Electric Measure and Program Savings

		Measure Counts		Unit Savings		Total Program Savings		
		# of Accounts	# of Items Installed	Heating & Other (kWh)	Cooling (kWh)	Heating & Other (MWh)	Cooling (MWh)	Total (MWh)
Non-Weather Sensitive Measures								
Refrigerators	Multifamily	3,675	3,867	674		2,606		2,606
	Mobile Homes	310	817	674		551		551
	Single Family	1,802	1,804	674		1,216		1,216
Lighting (CFL's)	Multifamily	3,869	8,747	29		254		254
	Mobile Homes	425	2,835	29		82		82
	Single Family	4,811	12,304	29		357		357
Water Heating								
Aerators	Multifamily	112	269	42		11		11
	Mobile Homes	84	899	34		30		30
	Single Family	228	497	34		17		17
Showerheads	Multifamily	105	150	84		13		13
	Mobile Homes	72	379	104		39		39
	Single Family	197	269	104		28		28
Pipe Wrap	Multifamily	2	2	42		0		0
	Mobile Homes	27	27	53		1		1
	Single Family	15	15	53		1		1
Tank Wraps	Multifamily	4	4	112		0		0
	Mobile Homes	25	56	140		4		4
	Single Family	41	42	140		6		6
Program Totals		14,089				5,216		5,216

Table 7-16: PG&E Gas Measure and Program Savings

		Measure Counts		Unit Savings	Total Savings
		# of Accounts	# of Items Installed	Heating & Other (Therms)	Heating & Other (Therms)
Non-Weather Sensitive Measures					
Water Heating					
Aerators	Multifamily	6,006	13,470	0.60	8,042
	Mobile Homes	1,828	7,382	0.80	5,877
	Single Family	21,581	47,510	0.80	37,821
Showerheads	Multifamily	5,238	6,495	1.79	11,634
	Mobile Homes	1,452	3,078	1.99	6,126
	Single Family	18,127	23,456	1.99	46,681
Pipe Wrap	Multifamily	75	75	1.00	75
	Mobile Homes	48	48	1.00	48
	Single Family	181	181	1.00	180
Tank Wraps	Multifamily	657	657	2.39	1,569
	Mobile Homes	371	371	2.59	960
	Single Family	5,148	5,148	2.59	13,319
DHW Replace	Multifamily	60	60	18.79	1,127
	Mobile Homes	128	128	18.79	2,405
	Single Family	502	502	18.79	9,433
Space Heating Measures					
Envelope					
Attic Insulation	Multifamily	130	130	19.90	2,587
	Mobile Homes	3	3	59.59	179
	Single Family	3,854	3,854	48.12	185,450
Caulking	Multifamily	5,219	5,219	0.78	4,045
	Mobile Homes	1,734	1,734	0.92	1,604
	Single Family	18,912	18,912	0.93	17,564
Weatherstripping	Multifamily	4,748	4,748	1.68	7,978
	Mobile Homes	1,658	1,658	3.09	5,117
	Single Family	18,858	18,858	3.14	59,298
Envelope Repair	Multifamily	4,088	4,088	2.86	11,702
	Mobile Homes	1,388	1,388	5.05	7,007
	Single Family	18,557	18,557	5.76	106,925
Evap Clr Cover	Multifamily	151	151	0.36	54
	Mobile Homes	468	468	0.68	320
	Single Family	2,156	2,156	0.65	1,408
Misc Env	Multifamily	5,094	5,094	-	-
	Mobile Homes	1,688	1,688	0.35	588
	Single Family	18,593	18,593	0.34	6,362
Heating System					
Furnace Filter	Multifamily	2,536	2,536	1.72	4,362
	Mobile Homes	1,481	1,481	3.07	4,543
	Single Family	11,256	11,256	3.04	34,203
Program Totals		70,683			606,592

Table 7-17: SDGE Gas Measure and Program Savings

		Measure Counts		Unit Savings	Total Savings
		# of Accounts	# of Items Installed	Heating & Other (Therms)	Heating & Other (Therms)
Non-Weather Sensitive Measures					
Water Heating					
Aerators	Multifamily	894	1,769	0.60	1,056
	Mobile Homes	227	734	0.80	584
	Single Family	2,387	4,975	0.80	3,960
Showerheads	Multifamily	840	967	1.79	1,732
	Mobile Homes	184	338	1.99	673
	Single Family	2,062	2,821	1.99	5,614
Pipe Wrap	Multifamily	12	12	1.00	12
	Mobile Homes	45	45	1.00	45
	Single Family	97	97	1.00	97
Tank Wraps	Multifamily	39	39	2.39	93
	Mobile Homes	35	35	2.59	91
	Single Family	407	407	2.59	1,053
DHW Replacement	Multifamily	3	3	18.79	56
	Mobile Homes	84	84	18.79	1,578
	Single Family	248	248	18.79	4,660
Space Heating Measures					
Envelope					
Attic Insulation	Multifamily	7	7	12.43	87
	Mobile Homes	0	0	0	0
	Single Family	371	371	32.02	11,881
Caulking	Multifamily	1,230	1,230	0	0
	Mobile Homes	232	232	1.11	258
	Single Family	2,537	2,537	1.11	2,826
Weatherstripping	Multifamily	1,250	1,250	1.11	1,391
	Mobile Homes	155	155	2.23	345
	Single Family	2,574	2,574	2.23	5,735
Envelope Repair	Multifamily	1,266	1,266	1.28	1,622
	Mobile Homes	250	250	3.87	968
	Single Family	2,636	2,636	4.02	10,623
Evap Clr Cover	Multifamily	0	0	0	0
	Mobile Homes	24	24	0.51	12
	Single Family	0	0	0	0
Misc Env	Multifamily	900	900	0	0
	Mobile Homes	163	163	0.24	38
	Single Family	1,851	1,851	0.26	484
Program Totals		14,089			57,576

Table 7-18: SoCalGas Gas Measure and Program Savings

		Measure Counts		Unit Savings	Total Savings
		# of Accounts	# of Items Installed	Heating & Other (Therms)	Heating & Other (Therms)
Non-Weather Sensitive Measures					
Water Heating					
Aerators	Multifamily	8,426	18,189	0.60	10,860
	Mobile Homes	526	3,457	0.80	2,752
	Single Family	13,646	25,803	0.80	20,541
Showerheads	Multifamily	8,392	11,501	1.79	20,600
	Mobile Homes	513	2,222	1.99	4,422
	Single Family	13,419	17,631	1.99	35,089
Pipe Wrap	Multifamily	129	129	1.00	128
	Mobile Homes	99	99	1.00	99
	Single Family	696	696	1.00	693
Tank Wraps	Multifamily	1,374	1,374	2.39	3,281
	Mobile Homes	87	87	2.59	225
	Single Family	1,796	1,796	2.59	4,647
DHW Replacement	Multifamily	82	82	18.79	1,541
	Mobile Homes	79	79	18.79	1,484
	Single Family	489	489	18.79	9,188
Space Heating Measures					
Envelope					
Attic Insulation	Multifamily	235	235	9.78	2,299
	Mobile Homes	0	0	-	-
	Single Family	768	768	27.57	21,174
Caulking	Multifamily	251	251	0.45	113
	Mobile Homes	215	215	1.14	245
	Single Family	820	820	1.03	847
Weatherstripping	Multifamily	16,597	16,597	1.13	18,743
	Mobile Homes	734	734	2.67	1,957
	Single Family	19,852	19,852	2.31	45,900
Envelope Repair	Multifamily	15,857	15,857	1.92	30,503
	Mobile Homes	416	416	3.86	1,607
	Single Family	18,804	18,804	4.19	78,855
Evap Clr Cover	Multifamily	175	175	0.23	40
	Mobile Homes	125	125	0.59	74
	Single Family	761	761	0.57	431
Misc Env	Multifamily	10,485	10,485	-	-
	Mobile Homes	530	530	0.30	161
	Single Family	12,780	12,780	0.33	4,223
Program Totals		39,464			322,721

7.6 Impacts of Measures with Increased Use

Table 7-19: PG&E Electric Measures with Increased Use

		Measure Counts		Unit Savings	Total Program Savings	
		# of Accounts	# of Items Installed	Cooling (kWh)	Cooling (MWh)	Total (MWh)
Cooling						
Evap Coolers	Multifamily	2,781	2,781	(189)	(527)	(527)
	Mobile Homes	682	682	(272)	(185)	(185)
	Single Family	10,724	10,724	(278)	(2,985)	(2,985)
A/C replacement	Multifamily	1	1	(45)	(0)	(0)
	Mobile Homes	60	60	(60)	(4)	(4)
	Single Family	309	309	(74)	(23)	(23)
Program Totals						(3,723)

Table 7-20: PG&E Gas Measures with Increased Use

		Measure Counts		Unit Savings	Total Program Savings
		# of Accounts	# of Items Installed	Heating & Other (Therms)	Heating & Other (Therms)
Heating System					
Duct Sealing	Multifamily	54	54	(2.95)	(159)
	Mobile Homes	26	26	(7.26)	(189)
	Single Family	847	847	(7.08)	(5,994)
Prog. Thermostats	Multifamily	376	376	(4.52)	(1,669)
	Mobile Homes	570	570	(11.83)	(6,741)
	Single Family	2,286	2,286	(10.86)	(24,830)
Furnace Repair	Multifamily	2	1	(10.12)	(23)
	Mobile Homes	76	33	(24.63)	(1,872)
	Single Family	516	238	(23.40)	(12,074)
Furnace Replacement	Multifamily	1	1	(26.47)	(26)
	Mobile Homes	33	33	(61.12)	(2,017)
	Single Family	238	268	(54.25)	(12,910)
Program Totals					(68,532)

Table 7-21: SoCalGas Measures with Increased Use

		Measure Counts		Unit Savings	Total Program Savings
		# of Accounts	# of Items Installed	Heating & Other (Therms)	Heating & Other (Therms)
Heating System					
Duct Sealing	Multifamily	6	6	(1.84)	(11)
	Mobile Homes	5	5	(4.60)	(23)
	Single Family	410	410	(4.32)	(1,771)
Furnace Repair	Multifamily	9	9	(5.39)	(49)
	Mobile Homes	76	76	(15.57)	(1,184)
	Single Family	745	745	(15.22)	(11,339)
Furnace Replacement	Multifamily	25	25	(11.01)	(275)
	Mobile Homes	94	94	(35.37)	(3,325)
	Single Family	2064	2064	(31.76)	(65,563)
Program Totals					(83,539)

Table 7-22: SDG&E Gas Measures with Increased Use

		Measure Counts		Unit Savings	Total Program Savings
		# of Accounts	# of Items Installed	Heating & Other (Therms)	Heating & Other (Therms)
Heating System					
Duct Sealing	Multifamily	1	1	(1.91)	(2)
	Mobile Homes	231	231	(5.36)	(1,239)
	Single Family	124	124	(5.15)	(639)
Prog. Thermostats	Multifamily	0	0	0.00	0
	Mobile Homes	104	104	(7.82)	(813)
	Single Family	129	129	(7.23)	(933)
Furnace Repair	Multifamily	86	86	(6.58)	(566)
	Mobile Homes	32	32	(18.90)	(605)
	Single Family	281	281	(16.35)	(4,594)
Furnace Replacement	Multifamily	0	0	0.00	0
	Mobile Homes	61	61	(40.46)	(2,468)
	Single Family	109	109	(37.35)	(4,071)
Program Totals					(15,929)

8 Measure-Level Savings

In the subsections that follow, we review savings for key individual measures in the LIEE program. For each measure, we provide a table that shows the range of savings estimates for each of the three previous LIEE evaluations, along with a range of savings reported for other studies we found (if any). The figures cited for the prior LIEE studies represent the range of average estimated savings by utility and housing type, but not by climate zone within these categories.[27] The methods used to conduct the measure-level literature search are explained in Section 8.1.

Methodologically, except for a very few studies that involved end-use metering, nearly all of the studies included here relied on statistical analysis of utility billing data, often in conjunction with *ex ante* engineering estimates of savings. While this implies that at some level savings estimates have been derived from actual changes in usage, savings estimates for individual measures may or may not reflect reality due to issues with the statistical modeling process. This is probably most true of measures with small impacts, such as furnace filters and individual water heating measures, particularly when these are bundled with other measures in the modeling process. We discuss some of these issues in more detail later.

As part of this discussion we have also included possible strategies for improving the reliability of estimates for the different measures on an on-going basis. A synopsis of the issues effecting savings estimates and the possible remedies is provided in Table 8-1.

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[27] Also, savings for SoCalGas in the 2001 study are not included in our ranges; the detailed table with these savings appears to have been inadvertently omitted from the published final report.

Table 8-1: Measure-level Issues and Approaches

Measure	Issues	Approach
Lighting	▪ Reduction in watts ▪ Retention ▪ Hours of use	▪ Record delta watts and location ▪ Follow up survey for retention ▪ Selective logging
Refrigerators	▪ Major driver of program savings	▪ Regression results are stable and consistent
Evaporative Coolers	▪ Proper use of equipment ▪ Interaction w/ AC	▪ Record condition of existing equipment in the tracking system ▪ Survey of participants to ascertain usage patterns
Evaporative Cooler Maintenance	▪ Prior and ongoing use of the system	▪ Same as above
Air Conditioning Installation	▪ Replacement of non-functioning units results in increased usage	▪ Record functionality, vintage and condition of AC unit being replaced
Furnace Replacement/Repair	▪ Replacement of non-functioning units results in increased usage	▪ Record functionality, vintage and condition of furnace unit being repaired or replaced
DHW Conservation	▪ Type of fuel used for heating DHW unknown	▪ Record fuel type in tracking system and/or update CIS system if applicable
Attic Insulation	▪ Unknown pre-treatment condition	▪ Record R-value and condition of insulation before treatment in tracking system
Air Sealing	▪ Small savings difficult to discern in regression analysis	▪ Conduct pre-treatment and post treatment blower door tests on a sample of homes to provide basis for estimating savings
Programmable Thermostats	▪ Savings dependent on occupant behavior	▪ Survey and/or thermal data logger study of a sample of participants

8.1 Scope of Measures Level Review

The purpose of this section is to examine the savings estimates for 2002 program participants in light of previous estimates of savings for individual measures for the LIEE program and other similar programs.

To conduct the literature review, we first searched for relevant evaluation reports from the following sources:

- BPA Publications database – www.bpa.gov/Energy/N/reports/evaluation/
- CALMAC Publications database – www.calmac.org
- CEE Evaluation Clearinghouse database – www.cee1.org/eval/clearinghouse.php3
- Energy Center of Wisconsin Library – www.ecw.org/ecw/librarycatalog.jsp?areaId=4
- International Energy Program Evaluation Conference Proceedings 1997 – 2003
- Northeast Energy Efficiency Partnership – www.neep.org
- Northwest Energy Efficiency Alliance – www.nwalliance.org/resources/evalreports.asp
- NYSERDA Evaluation reports – www.nyserda.org/evaluation.html
- ORNL Publications database – www.ornl.gov/ornlhome/publications.shtml

- PNL Publications database – www.pnl.gov/main/publications/index.asp

We also contacted several individuals active in the field of residential program evaluation. This led to identifying additional studies for Iowa and New England.

Although the initial search yielded more than 260 evaluation studies, many of these did not involve estimates of savings at the measure level, or were not particularly relevant to the LIEE program We thus narrowed the list down to 20 studies that contain either estimates of measure-level savings of relevance to the LIEE program, or other useful information related to the determinants of savings (such as measure retention for items like showerheads and light bulbs). Three of these are the prior impact evaluations of the LIEE program, and five are impact evaluations of individual utility direct assistance programs that were pre-cursors to the LIEE program.[28] The remainder were studies of other California residential programs or studies from elsewhere in the country.

Of course, it can be misleading to compare savings estimates across evaluations of programs that are disparate in climate, housing stock, demographics, and measure implementation protocols. We generally included studies related to residential refrigerator replacement (though we excluded refrigerator turn-in programs), CFL installations or water heating measures, but excluded studies outside California for measures such as furnace replacement and attic insulation.

8.2 Lighting

First-year electricity savings from the installation for compact fluorescent lights (CFL's) are a function of

- The wattage reduction between the existing incandescent bulb and the replacement CFL;
- The number of hours per day that the bulb is turned on; and,
- The fraction of program-installed CFLs retained through the first year

The LIEE program replaces up to five incandescent bulbs per home with CFLs, with the criterion that replaced bulbs must be used at least 3.5 hours per day. Setting aside retention issues for a moment, this minimum burn time would imply on the order of 50 to 75 kWh annual savings for the 60- and 75-Watt bulbs that probably make up the majority of bulbs replaced by the program.[29]

As Table 8-2 shows however, while other evaluations have shown per-bulb savings in the above range, the three prior LIEE program evaluations have consistently been lower.

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[28] We also made use of savings estimates from the DEER database (2001 update) as a reference point for some measures, even though strictly speaking these do not represent program evaluation results.

[29] The LIEE installation standards manual recommends replacing a 60-Watt incandescent with a CFL in the range of 15-18 Watts, and replacing a 75-Watt incandescent with an 18-20 Watt CFL.

Table 8-2: Reported CFL Savings

	Range across utilities and housing types (Annual kWh/bulb)
PY2002 LIEE evaluation	21 - 43
Prior LIEE evaluations	
2001	16 – 24
2000	22 – 29
1998	23 – 27
Other Studies[a] (8)	34 – 63[b]

[a] Ref. 1,3, 13, 18

[b] Excludes one outlier estimate of 128 kWh/bulb for PG&E 1991 Res. Energy Saver (Ref. 1)

Measure retention could at least partly explain this difference. Follow-up telephone surveys of program participants have shown relatively high *reported* retention of CFLs: survey data from the 2001 LIEE evaluation suggests about 80 percent retention of CFLs, and a survey conducted for 1995 participants in SCE's Direct Assistance Program indicated 90 percent retention (Ref. 18). But separate on-site inspections conducted as part of the latter study showed that the actual number of bulbs in place in participant homes was only 61 percent of what the tracking system indicated.

The actual hours of use may also be somewhat lower than the criterion for installation under LIEE. The 1995 SCE DAP study installed data loggers on 205 light fixtures with CFL replacements to capture hours of use. The study showed an average of 3.5 hours of daily use, with logged hours of use averaging 85 percent of that reported by occupants.

8.2.1 PY2002 Analysis

The regression models showed a fair amount of variation in the savings estimates for CFL's. In the individual utility regression models, savings per product ranges from a low of 21 kWh per year (SCE) to a high of 43 (PG&E.) Further analysis indicates that the lighting savings may be inflated (particularly for PG&E) by savings from general program effects, possibly resulting from the energy education component of the program. When program effects are explicitly modeled, the lighting savings drop substantially. Since lighting is installed in most homes and is largely collinear with program participation, it is not possible to distinguish the program effects from lighting savings. Although the distribution of savings to measures and general program effects is imperfect, the total program savings should be reasonably accurate. This issue is explored further, including a comparison of the alternative models, in Section 6.6 and Appendix A-2.

8.2.2 Alternative Strategies for Assessing Savings

A more detailed assessment of the savings from CFLs installed under the program could be obtained by:

- tracking the wattage of existing and replacement bulbs;
- tracking the CFL installations by location in the home (e.g., dining room, outdoors, bedroom, etc.)
- collecting on-site data to determine the retention rate for bulbs installed by the program; and,
- collecting on-site light logger data to determine average hours of use by location.

8.3 Refrigerators

Refrigerator savings are determined by the difference in electricity consumption between the existing unit and the replacement unit. In general, refrigerator electricity consumption is a function of type, size and age of the unit, whether the unit is functioning properly, and the temperature of the space in which it is located. All other factors being equal, older refrigerators use more electricity, with the all-time highest consumption by refrigerators from the late 1970s. Side-by-side models use more electricity than top- or bottom-freezer models, partly because these tend to have features such as through-the-door water and ice.

The key LIEE program installation policies for refrigerator replacement are:

- only primary refrigerators may be replaced;
- the existing unit must be at least 10 years old;
- the replacement unit must be at least as large as the existing unit, but no larger than 19 cubic feet;[30] and,
- the replacement unit must be Energy Star labeled and be automatic defrost.

These installation policies place some boundaries on the likely savings from the program. The age restriction means that refrigerators replaced by the program in 2002 could have been manufactured as recently as 1992, though in practice the average age would likely be older than this. The size restriction implies that most refrigerators replaced under the program are probably in the 18-19 cubic foot range. Since side-by-side refrigerators tend to be larger than this limit, the majority of refrigerators replaced by the program are probably top-freezer models.

An example of a similar effort in the residential low income market is Efficiency Vermont’s Low Income Single Family Program, started in 2000. In this statewide program operated in Vermont, data loggers are used to determine actual usage while the auditor is in the home. Refrigerators that are found to be using excessive amounts of

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[30] Replacement units up to 23 cubic feet are allowed if a single unit is replacing multiple existing units.

electricity are replaced with new, efficient models. This approach differs from the LIEE program in that the higher users are identified and replaced, which would be expected to achieve higher average savings, albeit with fewer installations. The savings claims are based on comparing the metered use of the old unit to the rated use for the new refrigerator. In 2001, 70 refrigerators were installed, estimated to save an average of over 1,300 kWh per year. (Ref. 21)

The table below shows estimated savings for replacing typical older top-freezer refrigerators with a new (2002) 18 cubic foot Energy Star labeled unit.

Table 8-3: Refrigerator Savings by Age of Existing Unit

Age of existing unit	Rated average electricity use of existing unit[a] (Annual kWh)	Estimated savings (annual kWh)[b]
10 years (1992)	811	452
15 years (1987)	973	630
20 years (1982)	1,174	851
25 years (1977)	1,621	1,343

[a] for average top-freezer automatic defrost model (source: AHAM "Energy Efficiency and Consumption Trends")

[b] based on usage for a typical 2002 18-cubic foot, top-freezer, Energy Star labeled refrigerator with rated usage of 440 kWh. Savings also assume that usage for existing unit is 10% higher than rated.

These estimates agree fairly well with savings estimates from previous LIEE evaluations (Table 8-4), assuming that the average age of refrigerators being replaced by the program is on the order of 15 to 20 years.

Table 8-4: Reported Refrigerator Replacement Savings

	Range across utilities and housing types (Annual kWh)
PY2002 LIEE evaluation	665-700
Prior LIEE evaluations	
2001	665 – 795
2000	645 – 712
1998	542
Range of 2001 DEER Values	206 – 454
Other Studies[a] (8)	89 – 1,380

[a] Ref. 1,3, 8, 12, 13, 16, 21

8.3.1 PY2002 Analysis

The savings estimates derived from the regression analysis and pre/post are highly consistent, and the refrigerator savings are stable in all of the alternative regression models. These results suggest a high degree of reliability in the estimated savings from installing efficient refrigerators.

8.3.2 Alternative Strategies for Assessing Savings

Refrigerator replacement savings are large enough to be readily detectable from utility usage histories, and the savings estimates that have historically been derived in this way appear to be consistent with the types and vintages of units that are likely to be replaced by the program. However, if more precise estimates of savings from refrigerator replacement are needed, before and after metering of a sample of refrigerators replaced under the program could be employed.

8.4 Evaporative Coolers

Two measures related to evaporative coolers are installed under the LIEE program:

1. New evaporative coolers (window or portable) are installed in homes with working air conditioners in hot/dry climate zones
2. Existing non-functional evaporative coolers are repaired under the program.

8.4.1 Evaporative Cooler Installation

An evaporative cooler produces effective cooling by combining a natural process - water evaporation - with a simple, reliable air-moving system. Fresh outside air is pulled through moist pads where it is cooled by evaporation and circulated through a house or building by a large blower. As this happens, the temperature of the outside air can be lowered as much as 30 degrees.

Probably because evaporative coolers add moisture to the air and blow it around, they are sometimes knows as "swamp coolers." Evaporative coolers can work wonderfully well, provided the outside air they are drawing in is dry and desert-like. As the humidity increases, however, the ability for them to cool the air effectively decreases. Simply put, swamp coolers were not designed to work in swamp-like conditions.

Air conditioning, on the other hand, became popular because of its ability to cool the air, no matter what the humidity might be. Even on humid days, room and central air conditioners can lower the temperature to a thermostatically controlled temperature. They also use as much as four times as much electricity than evaporative coolers do, and they are more expensive to install and maintain. Air conditioners can require ozone-damaging refrigerants, and they recirculate the same air over and over.

Fairly popular in desert areas, evaporative coolers will work fine most of the time in California's more humid climates. Sacramento, for example, averages about 30 percent humidity on a typical hot summer afternoon, still dry enough for evaporative cooling to work effectively.

8.4.2 Factors Affecting Savings

The *Statewide P&P Manual* states that evaporative coolers can only be installed in homes that have a functional refrigerant-based air conditioning system.[31] The underlying logic is

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[31] The installation and maintenance of evaporative coolers is also restricted to climate zones that are conducive to their use.

that the evaporative cooler supplants the air conditioning during certain parts of the day. However, in order to cool their house even more, some customers use their air conditioner and evaporative cooler simultaneously, thus increasing rather than decreasing their electricity use. One study found that 25 percent of the participants in Southern California Edison’s Conservation Assistance Program (CAP), which was designed to reduce energy consumption for its low-income customers, used both appliances simultaneously. [32]

Running both appliances simultaneously also means that for one of the two appliances the optimal conditions for its performance cannot be met, resulting in a further degradation of savings. If one operated both appliances with some windows and doors open, then the performance of the air conditioner would be degraded. On the other hand, if one operated both appliances with all the windows and doors shut, then the performance of the evaporative cooler would be degraded.

This issue was explored in the telephone survey conducted as part of the 2000 LIEE evaluation. Sixty three respondents who had received an evaporative cooler were asked “now that you have the evaporative cooler, do you cool your home more, less, or about the same as you did prior to receiving the evaporative cooler?” Forty four percent of the respondents said they cooled their home more, 14 percent said less, and 40 percent said about the same (2% did not know). Unfortunately, the question does not clearly distinguish changes in usage for the air conditioning system versus the evaporative cooler.

8.4.3 PY2002 Analysis Results

The savings from this measure are highly variable and difficult to assess through the regression analysis. The lower usage during the pre-period, as discussed elsewhere, could have an effect on our ability to identify savings relating to cooling measures from the billing analysis.

No savings for cooling measures were found in the SDG&E model. PG&E showed increased usage for homes with evaporative cooler installations, possibly reflecting nonfunctioning cooling equipment in the pre-installation period, increased use during the post period or incorrect usage of the new equipment. SCE’s cooling model showed some savings for this measure, but the savings are unstable and become statistically insignificant when the standard errors from the bootstrapping analysis are applied.

8.4.4 Approaches to Assessing Savings

An in-depth assessment of savings from evaporative cooler installations would require field data on the extent to which people use the evaporative cooler instead of the existing air conditioning system, as well as the energy performance of these systems. The behavioral element could well be a function of the capacity and location of the installed

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[32] Ridge, Richard. "Energy Conservation for Low-Income Families: The Evaporative Cooler Experience," Evaluation Review, April, 1988.

window or portable unit in relation to the type and capacity of the existing air conditioning system.

Table 8-5: Reported Evaporative Cooler Installation Savings

	Range across utilities and housing types (Annual kWh)
PY2002 LIEE evaluation	264-377 (SCE only)
Prior LIEE evaluations	
2001	98-405
2000	45-618
1998	237-354
Range of 2001 DEER Values	333 - 5056
Other Studies (none)	

8.5 Evaporative Cooler Maintenance

Evaporative cooler maintenance is performed when an existing operational evaporative cooler is not functioning properly. As with evaporative cooler installation, homes that receive this measure must also have a functional refrigerant-based air conditioning system.

The issues here are related to those of evaporative cooler installation: to what extent do participants use the evaporative cooler in place of the existing air conditioning system? Since the existing evaporative cooler is functional in this situation, there is also the question of the extent to which the existing system is used prior to repair under the program.

Table 8-6: Reported Evaporative Cooler Maintenance Savings

	Range across utilities and housing types (Annual kWh)
PY2002 LIEE evaluation	74-106 (SCE), 358-512 (PG&E)
Prior LIEE evaluations	
2001	47 – 95
2000	(not reported)
1998	19 – 20
Other Studies (none)	

8.5.1 PY2002 Analysis Results

Similar issues apply to this measure as evaporative cooler installations. Both the SCE and PG&E models showed savings for this measure above the level of the previous evaluations. The PG&E cooling model shows surprisingly high and robust savings. The model was checked for outliers, collinearity with other measures, and the standard errors were calculated using the bootstrap methodology. These diagnostic tools confirm the presence of these savings.

8.6 Air Conditioning Installation

New air conditioners (window/wall or central) have been installed under the program since 2001 under the Rapid Deployment initiative. Air conditioners may not be installed if there is a working air conditioner in the home that is less than 10 years old. This leaves open the possibility that some air conditioners installed under the program are non-functional, with the result of an increase in electricity consumption following participation in the program.

For functional older units that are replaced under the program, the savings depend on the difference in efficiency (EER) between the existing and replacement units, as well as the annual hours of operation. In 2002, the minimum EER for central systems was increased to 10.3 - 10.6 (depending on the type of system), and to 10.7 for window/wall units.[33] Replacement central split systems must also have a thermostatic expansion valve (TXV), which improves the performance (and comfort) from the system when the refrigerant charge or airflow are not optimal. Air conditioners are installed in climate zones not covered by evaporative coolers, or where the temperature regularly exceeds 100F. The majority of installations for 2002 participants were in Climate Zones 8, 9 and 10 in southern California.

8.6.1 Central Systems

The 2001 DEER database provides default estimates (by housing vintage and climate zone) of annual savings from replacing older central air conditioners (SEER 10) with a newer more efficient model (SEER 12 or 13). For the three climate zones that dominate the replacements by 2002 LIEE participants, the DEER savings estimates range from about 70 to 110 kWh per year for older homes. These estimates are based on SEER rather than the EER specifications used by the program, and in any event, the vintage and efficiency of the units being replaced by the program is unknown.[34]

Estimates for the savings from the LIEE program in previous years are available only for 2001 participants, but the indicated savings are generally considerably higher than the DEER database would indicate. A more direct comparison of the estimated 2001 LIEE savings for single-family homes and the DEER estimates shows 205 kWh/year savings for the former for Climate Zone 10, compared to 84 kWh/year for the latter for older homes upgrading from SEER 10 to SEER 13 in the same climate zone.

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[33] The policy in 2001 was to install the highest available EER for the size in question, but not less than 10.0 for both central and window/wall systems.

[34] SEER (seasonal energy efficiency ratio) is meant to reflect seasonal performance. EER (energy efficiency ratio) is more reflective of efficiency under peak conditions.

8.6.2 Window/Wall Air Conditioners

The Association of Home Appliance Manufacturers (AHAM) publishes data on nation-wide trends in room air conditioner efficiency.[35] These data indicate that the average EER of room air conditioners rose from about 6.0 in 1972 to 8.9 in 1992 (the most recent year of manufacture eligible for replacement under the 2002 LIEE program). The efficiency upgrade from replacing a 1987 unit (EER of 8.0) with a new unit with a new unit at the program requirement minimum EER of 10.7 would result in about 25 percent electricity savings. Unfortunately, we found little data on the hours of use for window/wall air conditioners, which—along with output capacity—would be key to translating percentage improvements in efficiency into annual kWh.

8.6.3 PY2002 Analysis Results

The SCE cooling model shows modest savings for this measure. In PG&E's service territory, the homes with these measures show a modest increase in usage. This higher usage may indicate that some homes did not have functioning cooling equipment prior to the installation. It is possible that external factors affecting the consumption patterns during the analysis period (such as the Energy Crisis) also reduced potential savings associated with this measures. It was not possible to estimate the savings from cooling measures in SDG&E service territory due to a combination of the small sample size and moderate climate in addition to the confounding effects of the Energy Crisis.

Table 8-7: Reported Air Conditioner Installation Savings

	Range across utilities and housing types (Annual kWh)
PY2002 LIEE evaluation	80-114 (SCE), increased use (PG&E)
Prior LIEE evaluations	
2001	129 – 571
2000	(NA)
1998	(NA)
Other Studies (none)	

8.6.4 Alternative Strategies for Assessing Savings

Replacement of non-functioning units should be clearly indicated in the tracking system. More refined estimates of the savings from window/wall air conditioner replacement would require field data on the vintage and condition of a sample of units that are replaced by the program as well as monitoring for typical hours of use for units replaced by the program.

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[35] "Energy Efficiency and Consumption Trends — Energy Use Trends in Room Air Conditioners," AHAM. (www.aham.org)

8.7 Furnace Replacement/Repair

The main criteria for furnace repair or replacement are

1. the existing furnace is not operating properly,
2. the home is owner-occupied, and
3. the utility providing the weatherization service also supplies gas for the unit.

Replacement furnaces are required to be Energy Star labeled with at least a 90% AFUE rating for combustion efficiency.

Repairing or replacing an operable, but improperly functioning, furnace can be expected to result in gas savings, with the percentage savings in space heating consumption proportional to the ratio of the efficiency of the existing system to that of the replacement/repaired system. For example, replacing a furnace that is 70 percent efficient with a new 90 percent efficient furnace can be expected to reduce space heating gas consumption by about 22 percent (1-70/90).

Savings from furnace replacement have been estimated for several low-income weatherization programs in cold climates, but these estimates are not particularly relevant to the LIEE program for two reasons. First, furnace replacement under cold-climate programs is often undertaken on an efficiency basis for units that are in good working order but simply inefficient. Second, space heating in general is less discretionary in cold climates than in many of California’s climate zones.

The discretionary nature of space heating in some California climates highlights another wrinkle in estimating savings from furnace repair/replacement under the LIEE program: the fact that some furnaces that are repaired or replaced by the program are inoperable at the time of participation. Repairing or replacing these furnaces can be expected to result in an *increase* in gas usage. As part of a telephone survey conducted for the evaluation of 2000 participants, clients who received furnace repair/replacement were asked if they had a working furnace prior to participation. Of the 75 respondents, about two-thirds indicated that their furnace was inoperable.

To give a sense of the magnitude of the impacts associated with replacing operable and inoperable furnaces, we used the model coefficients from the 2001 study to estimate the annual change in gas consumption for a home in Fresno (Climate Zone 13, with about 2,500 heating degree days). The model predicts that a home with an inoperable furnace would show an increase in gas usage of about 325 therms per year following replacement, compared with a savings of 67 therms for a home with an operable furnace.

The regression models used in the 2000 and 2001 evaluations included terms to separately account for inoperable furnaces. Inoperable furnaces were defined according to a set criteria applied to billing history, i.e., a pattern of increased gas usage in the post-installation period. The 2001 model indicated a significant increase in gas consumption for households that received a furnace repair/replacement and were designated as having an inoperable furnace, compared to a decrease in consumption for households with operable furnaces that received these measures.

Differences in how participants with inoperable furnaces are treated probably underlie the wide range in estimated savings from these measures across the three prior LIEE evaluations (Table 8-8). The 1998 study did not distinguish between households with operable and inoperable furnaces; thus the savings on average are negative, reflecting a slight average increase in gas consumption. The 2000 study excluded households with inoperable furnaces from the savings estimates based on the telephone survey that was conducted. The 2001 study also includes modeling terms to separate impacts for households with inoperable furnaces from those with operable furnaces, although the determination was based on usage patterns due to the absence of survey data for that year.

For each of the three previous evaluations, the estimated savings from furnace repair is less than that for furnace replacement. This is consistent with the notion that replacement often means the additional efficiency gain from replacing a non-condensing furnace (typically 70% to 80% efficient) with a condensing model having a rated efficiency of 90 percent or more. Savings from furnace repair on the other hand, derive solely from incremental improvements in the existing furnace efficiency.

8.7.1 PY2002 Analysis Results

The results of the gas modeling indicate that usage increased in homes with new and repaired furnaces, as would be consistent with the assumption that the existing furnaces were inoperable in some homes prior to the replacement.

Table 8-8: Reported Furnace Replacement Savings

	Range across utilities and housing types (Annual therms)
PY2002 LIEE evaluation	Increased use
Prior LIEE evaluations	
2001	39 – 62
2000	84 – 147
1998	-3.2
Other Studies (none)	

Table 8-9: Reported Furnace Repair Savings

	Range across utilities and housing types (Annual therms)
PY2002 LIEE evaluation	Increased use
Prior LIEE evaluations	
2001	25 – 41
2000	16 – 43
1998	-15
Other Studies (none)	

8.7.2 Alternative Strategies for Assessing Savings

Record vintage and condition of furnace repaired or replaced in the tracking system. Clearly indicate if unit was non-functional prior to services

8.8 HVAC Filters

Washable filters are installed by the program for operable central HVAC equipment and window/wall air conditioners that are meant to have filters, but do not have a washable filter at the time of participation. Contractors are required to show customers how to clean the new filters.

In theory, better filter maintenance will help maintain equipment efficiency over time by delaying or eliminating the fouling of heat exchange surfaces. Clogged filters themselves also reduce airflow. For furnaces, this can increase the temperature rise across the furnace to the point where the furnace cycles on its high limit switch, which in turn decreases the efficiency of the furnace as it goes through many short cycles. The performance of air conditioners is also adversely affected by low airflow.[36]

However, we found no field studies to support (or refute) the notion that installing washable filters has an impact on energy usage. To save energy, the installation of washable filters would need to result in significantly better filter maintenance on the part of occupants where prior practice hampered HVAC equipment efficiency; the extent to which this actually occurs is unknown.

The 2000 and 2001 LIEE impact evaluation studies reported savings for furnace filters (Table 8-10). The way these estimates were derived, however, suggests that they may not be particularly reliable. The regression analyses for these two years bundled a number of measures together into a single term called "weatherization." In addition to filters, measures such as weatherstripping, programmable thermostats, and attic insulation were included in this bundle.

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[36] See for example, Parker, D.S, J.R. Sherwin and D. P. Shirey. 1997. "Impact of Evaporator Coil Air Flow in Residential Air Conditioning Systems." Florida Solar Energy Center. (http://www.fsec.ucf.edu/bldg/pubs/pf321/index.htm)

To account for the fact that some measures can be expected to produce more savings than others, weighting factors were used. A review of these weighting factors shows that one measure (attic insulation) has far more weight than the others, which means that it probably dominated the determination of the coefficient on which the savings are based. In essence, the reported savings for filters are probably mainly reflective of what the model determined was the relationship between deemed and actual savings for attic insulation—rather than any kind of significant relationship between changes in usage and the installation of filters.

In addition, the 2000 and 2001 evaluations only considered filter savings in the context of space heating, though dirty filters are an issue for air conditioning systems as well. This effect is not possible to model in the 2002 analysis, due to the inability to identify participants with functioning air conditioners.

8.8.1 PY2002 Analysis Results

In the gas model, furnace filters are bundled with other small space heating and envelope measures, and the savings are distributed to the measures based on the proportions of the deemed savings from the DEER report. Furnace filters were not included in the electric model.

Table 8-10: Reported HVAC Filter Savings

	Range across utilities and housing types	
	(Annual heating kWh)	(Annual heating therms)
PY2002 evaluation	Not estimated	1.7 - 3.1
Prior LIEE evaluations		
2001	11 – 18	1 – 4
2000	Not reported	2 – 5
1998	Not reported	Not reported
Other Studies (none)		

8.9 Water Heating Measures

The program installs several measures meant to save energy for water heating. These include two measures meant to reduce the amount of hot water used (showerheads and aerators) and two measures designed to reduce water heater energy losses (tank wraps and pipe insulation). These measures are widely implemented by low-income and non low-income programs throughout the country.

8.9.1 PY2002 Analysis Results for the Hot Water Package

In the regression model for the current evaluation, all water heating measures are included as a single variable. The package savings are then distributed to the individual measures proportionally based on the deemed savings presented in the DEER report.

There are significant challenges associated with estimating the hot water impacts from the billing analysis. With the LIEE program, there is the issue of uncertainty as to the fuel type of the water heater in the home that received a water heating measure(s). All four utilities have a mechanism to track water heater fuel, but these indicators are often missing and not always accurate. Yet to measure the savings from water heating measures, it is important to know whether one is looking for gas or electric impacts in a given home. The previous three LIEE evaluations have attempted to surmount this hurdle by assigning water heater fuel type based on seasonal usage patterns. For example, gas use in the summer is typically higher for customers with gas water heaters than for those with electric water heaters.

Another major issue is that electric water and space heating are almost completely coincident, and the additional use associated with electric space heating during the analysis period tends to overwhelm the hot water savings. However, the savings from the hot water package tend to be highly variable, susceptible to outliers and to high standard errors. For SDG&E, the variation is sufficiently large using the bootstrapping standard errors that the estimated savings are not statistically significant. The estimates of conservation savings for the gas measures are equally unreliable, showing a high degree of variability related to the selection of the model parameters.

The same issue also arises in the gas model. Gas water and space heating are almost entirely coincident, and changes in the model sometimes resulted in savings shifting from space heating to water heating measures. An alternative model excluding the care rate/post period interaction showed significantly higher savings for the DHW package, suggesting that the estimates in this report may be understated.

8.9.2 Showerheads

Energy-savings (or “low-flow”) showerheads save energy by reducing the amount of water used during showering. The savings depend on the flow rate of the existing showerhead compared to the replacement showerhead, how much the shower is used, whether people change the mix temperature of their showers after receiving a new showerhead, and the fraction of households that remove the new showerhead because they are dissatisfied with it.

We found a fairly wide range of estimated savings for showerheads (Table 8-11). Methodologies differed across these study, however. Probably the most reliable are two field studies that relied on actual before/after measurements of hot water consumption or showerhead flow rate (Ref. 2 and 15) for homes with electric water heat. These two studies produced similar estimates of the savings from showerhead replacement of about 200 to 230 kWh/year per showerhead.

Less reliable are estimates of showerhead savings that rely on statistical disaggregation of utility usage histories (Ref. 11 and 15) — including the prior LIEE evaluations. Water heating measures are typically bundled into a single regression estimator, making it difficult to know the extent to which the results are driven by measures in the bundle other than the one of interest. (See preceding discussion of savings from filters.)

A study of retention of showerheads by mid-1990's participants of the Direct Assistance Programs that were pre-cursors to LIEE showed showerhead retention rates in the range of 80 to 90 percent (ref. 9).

Table 8-11: Reported Showerhead Savings

	Range across utilities and housing types	
	Electric water heat (kWh/year)	Gas water heat (therms/year)
PY2002 LIEE evaluation	30-135	2
Prior LIEE evaluations		
2001	66 – 109	7 – 8
2000	200 – 240	6 – 9
1998	174 – 298	7 – 16
Other Studies (5)[a]	78 – 608	8 – 22
Range of 2001 DEER Values	148 – 186	8 - 10

[a] Ref. 1 (electric), 2 (electric), 3 (gas and electric), 11 (gas), and 15 (electric)

8.9.3 Aerators

Similar to showerheads, aerators save energy by reducing the amount of hot water used at bathroom and kitchen sinks. The savings can be expected to be less than for showerheads, both because less hot water is used at these fixtures, and some hot water use is batch use (e.g., filling the sink to rinse dishes) where the flow rate is irrelevant.

As can be seen in Table 8-12, reported savings for this measure both from the previous LIEE evaluations and the few other studies we found, indicate that aerator savings are about one-third to one-half that of showerheads.

Table 8-12: Reported Aerator Savings

	Range across utilities and housing types	
	Electric water heat (kWh/year)	Gas water heat (therms/year)
PY2002 evaluation	12-56	0.6-0.8
Prior LIEE evaluations		
2001	26 – 43	2.6 – 3.6
2000	41 – 48	0.9 – 1.4
1998	Not reported	Not reported
Other Studies (2)[a]	85-86	3 – 4
Range of 2001 DEER Values	58 – 77	3 – 4
[a] Ref. 3 (gas and electric), 11 (gas), 15 (electric)		

8.9.4 Water Heater Wrap

Adding insulation to a water heater increases the resistance to loss of heat from the tank, thereby saving standby energy. The program may add an insulation wrap to water heaters that lack one, as well as replace an existing water heater wrap that is not up to the program standards.

The savings from water heater wrap depend on the temperature difference between the hot water in the tank and the surrounding space. The existing level of tank insulation (either integral to the water heater at the time of manufacture or added in the form of existing tank wrap) is also important. Older water heaters have less integral insulation than newer ones. This may explain why older studies (e.g., ref. 2) show higher savings.

The mid-1990’s DAP retention study (ref. 9) showed 75-90 percent retention of water heater blankets.

Table 8-13: Reported Water Heater Wrap Savings

	Range across utilities and housing types	
	Electric water heat (kWh/year)	Gas water heat (therms/year)
PY2002 LIEE evaluation	70-185	2-3
Prior LIEE evaluations		
2001	88 – 145	9 – 11
2000	163 – 192	5 – 7
1998	138 – 239	6 – 13
Other Studies (3)[a]	242 – 714	6 – 12
Range of 2001 DEER Values	200 – 264	11 - 14
[a] Ref. 2 (electric), 3 (gas and electric), 11 (gas)		

8.9.5 Alternative Strategies for Assessing Savings

Better determination of the savings from water heating measures could be obtained first by adding water heater fuel type to the program tracking system. Additionally, estimates could be improved based on the number of bedrooms, as a proxy for occupancy, in the home.

8.10 Attic Insulation

Attic insulation reduces thermal loss through the ceiling portion of the thermal shell. Many variables affect the heating and cooling savings that result from attic insulation: the insulated square footage, the existing and final insulation R-values, the quality of the insulation installations (before and after participation), the efficiency of the heating and cooling equipment, thermostat settings, and of course climate.

Aside from climate and insulated square footage—which, though widely variable across the state, are known for any particular participating household—the amount of existing insulation is probably the most critical determinant of savings from this measure. The largest savings are associated with adding the first few inches of insulation to an uninsulated attic space; thereafter, the incremental savings for each additional inch of insulation decline substantially. Thus, adding six inches of insulation to an attic that has no existing insulation will save significantly more heating and cooling energy than adding six inches on top of an existing six inches of insulation.

The LIEE program standards are to insulate ceiling areas with R-11 or less existing insulation up to R-30 in climate zones with less than 5,000 heating degree days, and to insulate areas with R-19 or less to R-38 in colder climate zones.

Though several studies in cold climates have estimated the savings from attic insulation, we do not believe these to be applicable to the LIEE program due to the climate differences and the probable differences in typical existing insulation levels. The three prior LIEE evaluations estimated the savings from attic insulation (Table 8-14); however, the range of savings is fairly wide.

8.10.1 PY2002 Analysis Results

Attic insulation is a separate term in the gas model. Savings are estimated by comparing the use in homes with attic insulation to the homes receiving insulation through the program in PY 2002. Given the protocols to install insulation wherever it can feasibly be accomplished, homes not treated in PY 2002 were assumed to be fully insulated. This assumption may introduce some error into the analysis, as there may be some buildings that were not treated because they could not be insulated.

In the electric model, it was not possible to estimate the savings from attic insulation due to a combination of the relatively small number of observations, mild climate and increase use among homes with electric space heat from the pre to the post periods. Cooling savings from attic insulation also could not be modeled since it is not possible to identify which participants had cooling equipment in use during the analysis period.

Table 8-14: Reported Attic Insulation Savings

	Electricity for heating (kWh/year)	Electricity for cooling (kWh/year)	Gas for heating (therms/year)
PY2002 LIEE evaluation	Not estimated	Not estimated	12 - 59
Prior LIEE evaluations			
2001	157 – 288	50 – 208	26 – 42
2000	35 – 82	44 – 111	10 – 24
1998	65 – 335	-40 – 216	3 – 30
Other Studies (none)			

8.10.2 Alternative Strategies for Assessing Savings

The program tracking system currently provides data on the square footage that is insulated for each home. Improvements in the estimate of savings from this measure could be obtained by adding the R-value of existing insulation as well.

8.11 Air Sealing: Caulking, Weatherstripping and Outlet Gaskets

Caulking of cracks, weatherstripping doors, and installing gaskets under electrical outlet covers are all related in that they are expected to save heating and cooling costs by reducing air leakage. The program also addresses air leakage through penetrations by allowing repairs to broken windows, rotted doors and door frames, and holes in the building shell.

Without on-site testing, estimating the savings from these leakage reduction strategies is difficult. In general, leakage in homes, is a complex and highly variable phenomenon, governed by many factors: the size and location of penetrations in the building shell, pressure differences between the living space and the outdoors due to building stack effect, the effect of wind, and the operation of air handlers and appliances such as exhaust fans and dryers.

The introduction of blower doors in the 1980s revolutionized air sealing efforts by providing a means of quantifying building leakage under controlled conditions and identifying major air leakage sites.[37] For this reason, many low-income weatherization programs rely on blower doors to guide air sealing efforts. The large body of field experience with blower doors has shown that in many parts of the country, the largest air leakage pathways are often hidden penetrations such as plumbing soil stacks. The physics of air leakage also indicate that the most important leaks to seal from an energy-savings standpoint are those that are located down low in the building shell or up high, where pressure differences due to the stack effect are largest. Electrical outlets, windows and doors on the other hand, are often located near what is termed the "neutral-pressure plane"; i.e. the point in the building shell where there is no pressure difference due to stack effect.

Table 8-14 below shows the reported savings for caulking and weatherstripping from the three prior evaluations of the LIEE program (savings for outlet gaskets were not separately estimated for any of the studies.) The two measures were combined for the 1998 evaluation, but separated in the 2000 and 2001 study models.

The estimated savings are generally small. The reliability of these estimates is also somewhat questionable, since they are derived from combined estimated savings for a bundle of "weatherization" measures that also includes attic insulation, which could be expected to dominate the savings from this bundle.

Table 8-15: Reported Savings for Caulking and Weatherstripping.

		Heating		
		Electricity (kWh/yr)	Gas (therms/yr)	Cooling (kWh/yr)
PY2002 Evaluation	Caulking	Not estimated	.4 – 1.1	Not estimated
	Weatherstripping	Not estimated	1 – 3	Not estimated
Prior LIEE evaluations				
2001	Caulking	16 – 24	1 – 5	1 – 5
	Weatherstripping	11 – 21	2 – 5	1 – 5
2000	Caulking	4 – 8	1 – 3	2 – 8
	Weatherstripping	4 – 8	2 – 8	1 – 3
1998 Caulking and weatherstripping		10 – 50	1 – 4	-6 – 32
Other Studies		(no relevant studies found)		

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[37] See Keefe, David, "Introduction to Blower Doors," *Home Energy*, January/February 1994, and "Air Sealing in Occupied Homes," *Home Energy,* November/December 1995.

8.11.1 PY2002 Analysis Results

Space heating measures were not modeled for electrically heated homes. In the gas model, these measures are bundled into a single regression coefficient including weatherstripping, caulking, minor home repair, outlet gaskets, furnace filters, and evaporative cooler covers. All of these measures are expected to have relatively small savings, so it is not expected that any single measure would have a disproportionate impact on the results. The savings from the coefficient are distributed proportionally to the measures according to the saving estimates in the DEER report.

8.11.2 Alternative Strategies for Assessing Savings

Improving estimates of the savings from the air sealing efforts implemented by the program would start by conducting before and after blower door tests on a sample of LIEE homes to gauge the degree to which the program reduces air leakage under standardized blower door depressurization. These measurements could then be combined with additional information about the climate and housing stock to translate blower-door measured leakage reduction into the likely reduction in air infiltration under natural conditions using generally accepted methods.[38]

8.12 Programmable Thermostats

The underlying logic behind installing programmable thermostats is that they reduce heating and cooling energy use by enabling households to automatically lower the heating setpoint or raise the cooling setpoint at night or when no one is home.

Savings from thermostat setback are a function of how much the occupant sets back the thermostat, for how long, as well as the thermal integrity of the home and the climate in which it resides. Compared to not setting back the thermostat, a widely-quoted rule of thumb (derived from modeling and limited field studies in the 1970s) is for 1 percent savings for each degree that the thermostat is routinely set back for an eight hour period. The percentage savings are higher in milder climates: for California locations such as San Francisco and Los Angeles, one source estimates about 1.5 to 2 percent heating savings for each degree setback.[39]

From a programmatic standpoint, the savings that derive from the installation of programmable thermostats must also account for the extent to which the households that receive this measure were practicing manual setback prior to participation, as well as the extent to which occupants use the programmable features of the thermostat following installation. One Connecticut utility study found that about one in five households that had been given a free programmable thermostat were subsequently found to not be setting back at all, and only about a third were using the programmable features of the

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[38] See, e.g., Meier, Alan, "Infiltration: Just ACH_{50} Divided by 20?," in *Home Energy,* January/February 1994.

[39] Nelson, Loren. "Reducing Fuel Consumption with Night Setback," ASHRAE Journal, August 1973.

thermostat.[40] In addition, a 1999 survey of Wisconsin households suggests that it is more the occupants than the device that determines whether the thermostat is set back: households so inclined will set back regardless of whether they have a manual or an automatic thermostat, and those disinclined to set back will not do so even if they have a setback thermostat.[41] Both of these findings suggest that there will be a non-trivial fraction of program participants where no savings result from the installation of a setback thermostat. We were able to locate one study (from Canada) looking at actual savings from the installation of setback thermostats in homes (Ref. 4).

The program policy for the installation of programmable thermostats is somewhat confusing. In addition to noting that an existing programmable thermostat may not be replaced, the program and policy manual states that:

> “A programmable…thermostat may be installed only when central air conditioning and/or one of the following types of heating systems is present: gas wall heaters, gas furnace, electric furnace, heat pump, electric resistance cable.”

But also that:

> “A programmable…thermostat may be installed only if :
> - the furnace is repaired or replaced; or
> - if there is no shut off on the existing unit and the home is in a CEC climate zone with over 2,000 heating degree-days…
> - if required by code.”

Analysis of the 2002 program tracking data shows that programmable thermostats installed by the program are not often associated with furnace repair or replacement, suggesting that it is the last two parts of the latter clause (no shut off, and code requirements) that drive the installation of this measure.

Setback thermostat savings were reported for the 2001 LIEE evaluation (Table 8-15). As with the other minor heating and cooling related measures discussed here, these savings estimates were derived from a single model coefficient for “weatherization” measures, and may not be a reliable indicator of the savings from setback thermostats per se.

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[40] Cross, David, and David Judd. “Automatic Setback Thermostats: Measure Persistence and Customer Behavior,” Proceedings of the 1997 International Energy Evaluation Conference, Chicago, Illinois.

[41] Nevius, Monica and Scott Pigg. “Programmable thermostats that Go Berserk? Taking a Scoial Perspective on Space Heating in Wisconsin,” Proceedings of the 2000 ACEEE Summer Study on Energy Efficiency in Buildings.

Table 8-16: Reported Setback Thermostat Savings

	Heating Electricity (kWh/yr)	Cooling Electricity (kWh/yr)	Heating Gas (therms/yr)
PY2002 Evaluation	Not estimated	Not estimated	Increased use
Prior LIEE evaluations			
2001	1 – 20	8 – 17	1 – 3
2000	not reported	not reported	not reported
1998	not reported	not reported	not reported
Other Studies (1)[a]	None	None	6%
Range of 2001 DEER Values	36 - 668		7 – 69

[a] Ref. 4

8.12.1 PY2002 Analysis Results

In the gas model, a regression variable was incorporated to estimate the savings for this measure. The coefficient was positive, indicating a modest increase usage in homes with this measure. Our literature review suggests that savings from this measure are highly dependent on behavior. The increase in use could result from a combination of the variability in savings due to behavioral patterns and the apparent impacts of the Energy Crisis on energy use in the post-installation period.

8.12.2 Alternative Strategies for Assessing Savings

A better sense of the impact of the installation of setback thermostats under the program could be gained by surveying a sample of participants about their thermostat practices before and after receiving a setback thermostat under the program. For further refinement and field validation, a sub-sample of these households could be mailed a small data logger to record indoor temperature over the course of a year.

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9 Discussion

The results of this analysis show savings for base measures (lighting, refrigeration and hot water conservation) are reasonably consistent with previous evaluations. Savings from measures with weather-sensitive effects, in general, were difficult to assess due to a number of internal and external factors. The following discussion considers possible effects of the California 2001 Energy Crisis, structural changes to the program and the CARE rate on the low income sector.

9.1 The California Energy Crisis

Since this analysis was designed to estimate program savings for 2002, the pre-installation period spanned late 2000 into 2002. The post-installation period begins in mid-2002 and continues through the end of 2003.

There are indications in the data and regression model that suggest usage during the pre-installation period was depressed, as discussed below.

- Average usage shows a decline throughout 2001[42] and the first part of 2002, and then a rebound continuing through the end of 2003. Figure 9-1 reflects the monthly variation in the regression analysis after the effects of the known variables have been removed.
- The model consistently shows an increase in heating usage among all participants with electric space heating, regardless of whether conservation measures were installed. The additional usage increases proportionally as the temperatures get colder. While the regression analysis does not provide any insight into the cause of the change in usage, the pattern is consistent with lower thermostat settings in the pre-period and higher setting after the conservation measures were installed. These higher settings would effectively negate any savings for space heating measures.

This period encompasses the volatile period of time frequently referred to as the "California Energy Crisis." During 2001, shortages of electricity were common, resulting in rolling black outs in some areas, price increases, frequent public service announcements requesting California residents to reduce usage, and offers by the utilities and directly from the governor to discount bills for measurable reductions in usage.

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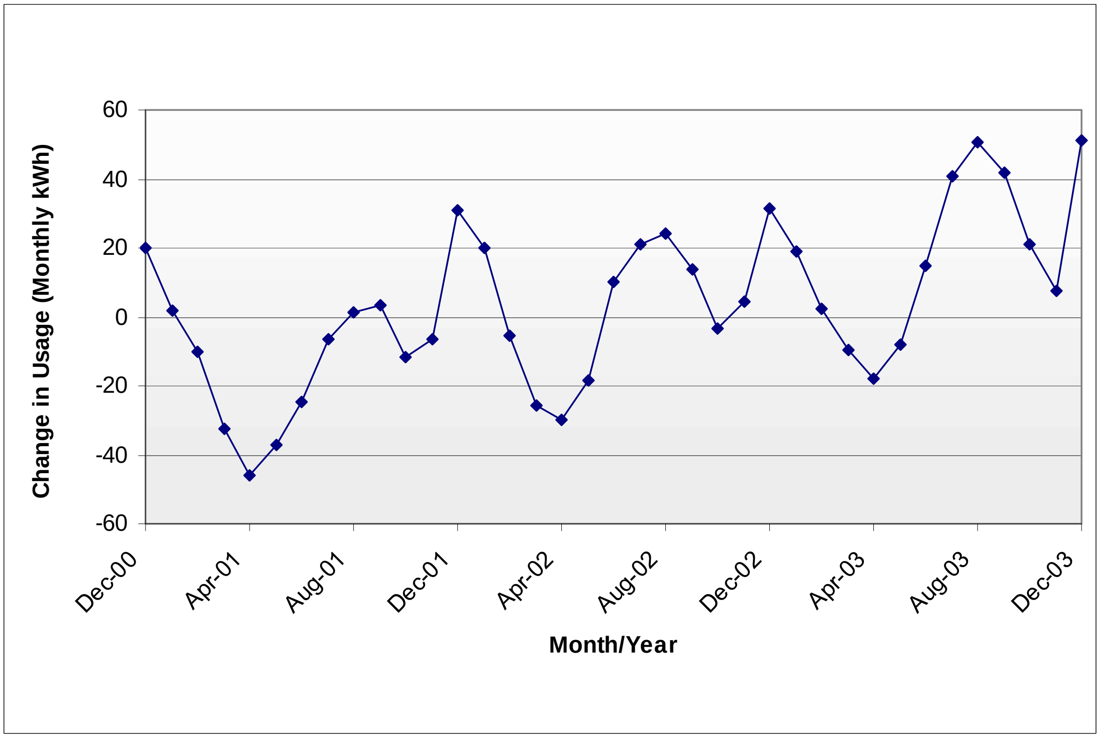
[42] Note that rolling blackouts occurred on January 17 and 18, 2001 with statewide rolling blackouts ordered two months later on March 19 and 20.

Figure 9-1: Monthly Average Variation in Electric Use



It has now been documented that these efforts were successful. There is substantial evidence that energy usage during the 2001 pre-period was significantly lower than in the previous years and that the lowered consumption continued into the year 2002. Bartholomew (2002) concluded that “Compared to 2000 summer loads, the 2001 CAISO summer electrical load decreased by 5.35 percent overall…” and “What is clear is that the load in California was reduced by a significant amount during the summer of 2001, and it is likely that state efforts to encourage energy conservation and consumer choices to conserve during the crisis helped to lower electricity demand.” Randazzo (2002) also found reductions in the range of 5 to 10% and Ridge (2004) cited a November 2002 *Sacramento Bee* report that “…utilities saw their per customer sales slump 6 percent to 9 percent in 2001.”

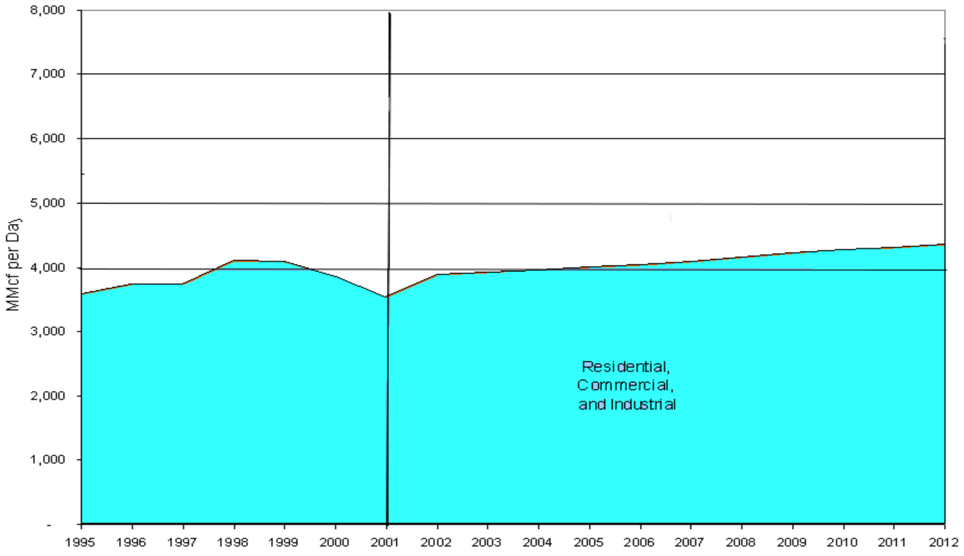
While usage began to rebound in 2002, it still remained below the level of previous years. The PY02 LIEE billing data shows an upward trend from the end of 2001 through the end of 2003. This is again supported by the available literature. Ridge quotes from the same *Sacramento Bee* article that “…nearly two years later, a partial relapse has occurred, but it's likely the state's consumers will use less electricity for years to come, according to utilities, academics and energy experts studying the legacy of California's power crisis.” One insight into the sustained motivation to save energy was provided by Lutzenhiser (2002) who found that 58.7% of respondents felt that changes made to conserve energy “had no serious effect” on their quality of life while another 14.7% reported that conservation steps had perhaps improved their quality of life.

The gas model also shows low savings for gas space and water heating measures, and it appears that the some of the same factors may be at play. The gas market experienced similar upheavals during this period. A spike in natural gas prices occurred in 2001 and 2002 due to high demand, tight supply, and price manipulation. When prices increased, producers increased drilling and gas-pipeline owners expanded pipeline capacity and storage facilities. At the same time, gas consumers conserved energy to decrease their demand and utility bills.

A slowdown of the national and California economies also contributed to lower demand. As a consequence, prices returned to the $4 to $6 per Mcf range after 2001. A Natural Gas Market Assessment California Energy Commission Staff Report in August of 2003 stated that “The California energy crisis during the winter of 2000-2001 resulted in high prices, especially at the southern California/Mexican border.” These price increases and supply problems led to a reduction in natural gas consumption. Figure 9-2 adapted from a slide presentation by Mignon Marks presented at a January 2003 workshop clearly shows a significant reduction in natural gas demand in the 2001 timeframe and a subsequent return to increasing demand.

Obviously the trends noted above will have an effect on the results of any billing impact analysis during this time frame. However, this effect is not likely to be uniform across all measures and measure categories. The steps that low-income consumers can take to lower their energy usage are more limited to low cost or no cost measures than the broader population. If buying a new refrigerator is not an option, there is very little that can be done to reduce the electricity used for refrigeration. However, the option of lowering your domestic hot water temperature or adjusting your thermostat set point is available to all. This suggests the possibility that savings from discretionary energy uses may be understated in this analysis.

Figure 9-2: Natural Gas Demand in California



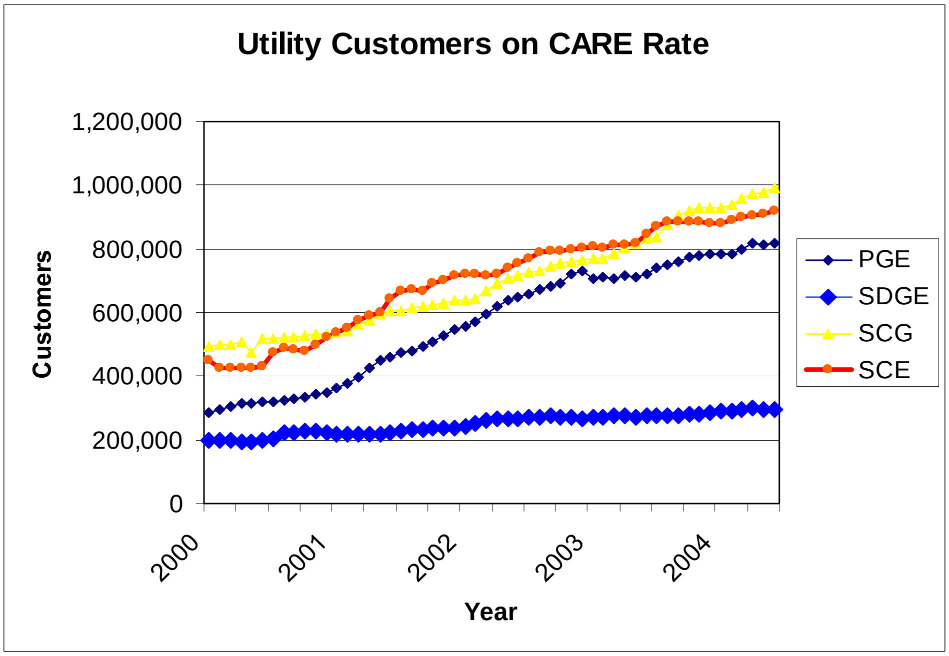
9.2 Other Considerations

A number of changes in the program structure mandated by the CPUC in 2001 may also have had an impact on PY 2002 energy savings. In Decision 01-05-033 dated May 3, 2001, the CPUC required the utilities to add the series of “rapid deployment” measures. Standardization among the four utilities was also being pursued in this time frame. For some of the utilities, this process involved combining a number of separate efficiency initiatives targeted at specific measures into a more comprehensive approach. Some of the utilities also returned to previously served participants to provide the more comprehensive set of measures. Thus, during the latter half of 2001, the utilities were redesigning the programs to cover a wider range of conservation upgrades, and these efforts extended into PY 2002. One of the utilities experienced further disruption in program implementation in that the program was briefly halted during 2001 and restarted at the beginning of 2002. Any inconsistencies in measure installation, assessment of eligibility or measure tracking during the transition phase may affect our ability to estimate PY 2002 savings. The net impact of these structural changes is to increase the uncertainty in the explanatory variables, making it more difficult to estimate program effects.

In the May, 2001 CPUC decision, the utilities were also directed to aggressively promote the CARE rate, i.e., the discounted rate offered by all of participating utilities to low income customers. The resulting increase in the penetration of utility customers on the CARE rate may also have an effect on the consumption patterns of the LIEE participants. The number of residents taking advantage of the CARE rate grew substantially between 2000 and 2004. The reduced rates may lessen the impact of the price signal. Figure 9-3 below shows the penetration of low income residents on the CARE rate from 1999 to 2004.

The impact of the CARE rate was incorporated directly into the regression analysis, with inconsistent results. In some models, it showed a small increase in use associated with the CARE rate. In other models, it was insignificant or showed a slight decrease in usage. In combination, these results suggest that the CARE rate does not have a consistent and measurable impact on energy use. However, these results should not be considered to be conclusive given that the study was not specifically designed to assess the impact of the CARE rate.

Figure 9-3: CARE Rate Penetration from 2000 to 2004



Another consideration is the possibility that some participant may decide to "buy back" energy savings in the form of increased comfort. Energy conservation may soften the financial burden of increasing thermostat settings (or decreasing them in the cooling season), and many participants may opt for a more comfortable house (Medgal, 1993). The increased comfort experienced by the participants through this effect is not easily quantified, but is often considered a program benefit.

9.3 Conclusion

The artificially depressed usage during the 2001 pre-installation period, modifications to program implementation and the substantial increase in penetration of the CARE rate may be working in combination to obscure program effects, particularly savings from weather-sensitive measures. Program tracking issues, particularly the inability to distinguish participants with functioning equipment prior to the installation, are certainly another major factor for some measures.

The lack of savings for space heating related measures found in the electric model and generally low level of savings in the gas model should not be considered to reflect the actual program impacts during a "normal" year. It is highly likely that enhanced program tracking and a return to more typical consumption patterns will show real and significant savings for at least some of these measures.

9.4 References

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10 Recommendations

The recommendations are listed below and described in more detail in the following paragraphs.

Table 10-1: Summary of Recommendations

Number	Topic	Description
10.1	Improve data collection	▪ Incorporate collection of additional data into regular program implementation (detailed list is provided in Table 10-2)
10.2	Set priorities for next evaluation	▪ Decide whether greater certainty on measure-level savings is necessary or household savings with adjusted deemed savings for measure-level estimates are sufficient
10.3	Establish appropriate time line	▪ If engineering and/or monitoring methods are preferred, bring in evaluators *prior* to the program year under review
10.4	Define the scope of the sample plan	▪ Select measures to be investigated ▪ Consider costs associated with each approach
10.5	Assessing savings from energy education	▪ Controlled experiment is best method for obtaining quantitative results, but likely to be cost prohibitive ▪ Consider qualitative assessment through surveys to assess whether impacts exist
10.6	Applying the results of this evaluation	▪ Measure-level estimates for most electric, non-weather sensitive measures are within a reasonable range for program planning and reporting purposes ▪ Estimates for weather sensitive measures and gas DHW conservation measures in the PY2002 should not be used for program planning ▪ PY2000 and 2001 evaluations may also suffer from some of the same shortcomings ▪ Deemed savings can be used for DHW conservation and weather-sensitive measures until better estimates are available
10.7	Postpone next evaluation until 2005	▪ The scheduled evaluation for PY2004 will be subject to many of the same problems found in the PY2002 evaluation ▪ Data collection could be modified for PY2005 and evaluation planning commence immediately to improve the results for PY2005

10.1 Improve On Site Data Collection

Regardless of the strategies selected for the next evaluation, improvements to the program data collection process should be a high priority. The lack of some important data describing pre-installation conditions added uncertainty to the billing analysis conducted for the 2002 participants. These data are not only necessary for program evaluation, but may be needed for program planning and reporting purposes as well. For example, tracking the number of inoperable furnaces or air conditioners replaced will assist program planners in estimating the non-energy benefits associated with the program. Table 10-2 presents a summary of the recommended additions to the program data collection.

Collecting a few additional key data points at the time of the site visit may reduce the uncertainty associated with future impact evaluations and improve the accuracy of program reporting without adding substantially to the program costs. The following data need to be collected and verified as part of program delivery:

- Fuel type used for space and water heating, and secondary space heating (if any)
- Presence of central air conditioning and if it is in use, i.e., whether the central air conditioner was used on a regular basis prior to the audit
- Number of room air conditioners present and number in use
- Type of all space and water heating equipment, including furnaces, water heaters and electric space heating units, and whether each piece of equipment was in use prior to the audit
- Type and quantity of existing attic insulation, and the type and quantity of the added insulation

The following demographic information should also be collected by all of the utilities with a reasonably consistent definition and format: number of occupants in the home, income category, housing type and senior citizen, and installation date. Verification procedures should be instituted or improved for these critical data.

More detail is also needed regarding multifamily buildings and mobile home parks. To improve the billing analysis, the total number of dwelling units in the building or mobile home park is needed. Also, a mechanism to connect each treated unit to the specific building or mobile home park should be put in place.

In addition to the items discussed above, all program and measure-level data files should contain an account number that can be linked to the billing history. Also, the data set provided for the impact evaluation should be completely consistent with the data set used for the AEAP report provided to the CPUC.

Table 10-2: Summary of Recommended Data Collection Improvements

Category	End Uses/ Measures	Additional Data Needed	PY 2002 Issue
Fuel Types	Primary space heating Secondary space heating Water heating	▪ Electricity, gas or other ▪ Utility providing service	Not consistently collected at the time of the site visit; questionable reliability
Heating System Types	Primary space heating Secondary space heating	▪ Furnace ▪ Boiler ▪ Heat pump ▪ Electric baseboard	Not collected or not available electronically
Presence of Major End Uses	Air conditioning	▪ Number of wall/window air conditioners ▪ Presence of central air conditioning ▪ Presence of evaporative cooler	Not consistently collected in the same format by all utilities
Condition of Existing Equipment	Furnaces Water heaters Wall or window air conditioners Central air conditioning Evaporative coolers	▪ In use or not in use ▪ Number of units in use for wall/window air conditioners	Not collected or not available electronically
Insulation	Attic Insulation	▪ Installation Details o Existing level and type of insulation o Installed level and type of insulation	Not collected or not available electronically
Attic Insulation		▪ Existing level of insulation for all participating homes	Not collected or not available electronically
Demographics		▪ Number of occupants ▪ Income category ▪ Housing type ▪ Senior citizen ▪ Installation date	Not consistently collected in the same format by all utilities
Multifamily Buildings and Mobile Homes		▪ Total number of units in the building or mobile home park ▪ Connect treated unit to the building or mobile home park	Not collected or not available electronically

10.2 Establish Priorities for the Next Evaluation

A critical component in designing the next impact evaluation is clearly defining the researchable questions and setting realistic expectations for the timeframe and costs. There are three possible directions to take in designing future impact evaluations:

(1) to focus primarily on savings at the household level and for major measures that could reasonably be expected to be estimated through a billing analysis, and use deemed savings for the smaller measures,
(2) to identify specific measures of interest and pursue engineering or monitoring strategies, or
(3) to rely solely on deemed savings.

The decision to employ one approach over the others depends on the desired results, available funds, availability of critical data, and the timeframe. The parties must decide whether a household focus, measure-level or deemed savings approach is most appropriate for the next evaluation.

10.2.1 Household Approach

One reasonable approach is to conduct program cost-effectiveness screening at the *household* level. Billing analysis is most effective when the savings are a significant portion of the total pre-installation consumption.[43] Deemed savings could be used to estimate the impacts of specific measures that cannot be obtained through the billing analysis. The advantage of using a billing analysis approach is that it uses readily available information and can reasonably be conducted after the completion of the program year, as long as the necessary program data are collected at the time of the audit.

Results from billing analyses are likely to be reliable for household savings and possibly some larger measures, such as refrigerators. While the improved data collection can help to provide critical inputs into the billing analysis, attempts to parse out savings by measure will continue to be hampered by many of the same issues encountered in the 2002 evaluation as well as in the earlier ones, such as the prevalence of measures with small impacts, separating savings for groups of measures that are often installed as a bundle and the high incidence of combined electric water and space heating.

The use of surveys from a sufficiently large sample of participants may be considered to collect data regarding household changes over time (e.g., changes in household size, addition/removal of energy using equipment, etc.) that could affect energy use other than the installation of efficient equipment, weather, and background economic conditions. Issues specific to the low income residential market need to be incorporated into the evaluation design, which may require developing a method to implement the survey relatively soon after the site visit. Theoretically, collecting data on all of the factors influencing energy use would result in a perfectly specified model. In the real world, we

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[43] If the savings are not a significant portion of the total pre-installation consumption, regression analysis can still be effective if the sample size can be increased as a way of increasing statistical power.

may not be able to identify all of the factors correctly or obtain accurate information from participants, and some level of misspecification may still exist.

Even with improved data collection, there is measurement bias inherent in any billing analysis due to the fact that overall changes in household consumption are used as a proxy to estimate the savings from efficiency programs although variations in the billing data may be caused by many factors external to the program. The effects of natural variations, at least at the household level, can be mitigated by the large sample size obtained by including all participants with sufficient billing history.

Another factor is that some heating and cooling system measures may be installed in homes where the existing equipment was malfunctioning or not functioning. In these cases, billing analysis will not be an effective tool for estimating savings. If these homes can be identified through the proposed enhancements to the program data collection, the billing analysis can be tailored to identify savings for air conditioner replacement (for example) in homes with functioning air conditioners prior to the installation.

10.2.2 Measure-level Approach

If the parties are more interested in obtaining greater certainty on specific measures, billing analysis is not the most effective method. Instead, we recommend identifying a specific subset of measures of interest and pursuing them through an engineering approach combined with pre and post monitoring. In the context of the LIEE program, these methods will tend to be more expensive and time-consuming, partly as a result of the nature of the program as currently implemented. These approaches will require involvement from the evaluator *prior* to program delivery for the year to be assessed, in order to ensure that pre-installation data from the treated homes is available.

While this approach is more expensive, costs could be contained by limiting the scope of the evaluation to one or two measures at a time. A criteria could be developed for establishing priorities and the timeframe. Some suggestions are provided below:

- Select measures with a major impact on total program savings and high uncertainty regarding the per unit savings (such as lighting)
- Select measures with substantial initial costs and variable per unit savings (such as evaporative coolers)
- Measures with low costs and small impacts on the overall program savings (such as low flow showerheads) may not be a priority

For lighting, the wattages of the existing and replacement bulbs could be recorded, and methods developed to assess short-term retention and hours per use. This information should be sufficient to make some reasonable estimates of actual installed savings. For evaporative coolers, a survey of participants may be implemented to assess behavioral patterns, combined with pre- and post-installation monitoring.

10.2.3 Deemed Savings

Finally, one could simply rely on deemed savings estimates for some or all measures. Deemed savings could be based on the results of previous LIEE evaluations, as supported by external sources. While the deemed savings will not reflect the variations in housing stock for the program year under review, it may be a reasonable approach given the expense involved in engineering and monitoring strategies and the issues with developing reliable estimate for some measures through a billing analysis.

Any low-income program that depends on on-site audits combined with direct-installation of all feasible measures, including refrigerators and air conditioners, will be very expensive to implement, conditions making its cost-effectiveness highly unlikely. Once on-site, a variety of less expensive measures, such as faucet aerators and low-flow showerheads can be installed at very low additional costs. As a result, even if such measures are unlikely to be cost-effective, little damage is done to the cost-effectiveness of the program by their installation. These measures certainly have some benefits to the participants that, in combination with the low incremental cost, may outweigh the uncertainty associated with the savings. The small impacts of these measures are well-documented and further attempts to pin down the specific impacts for LIEE participants may not be worth the money and effort expended.

10.3 Establish an Appropriate Time Line

Both engineering and monitoring techniques require access to detailed pre-installation information, such as the details of the existing conditions or metered usage *prior to* the installation. The LIEE program is designed to install all feasible measures in each home. Since measures are not selected on the basis of their cost effectiveness at the household level, no screening is conducted prior to installation. Consequently, the LIEE program protocols do not require the installers to collect extensive detail on the pre-installation conditions, and the program databases do not provide adequate information about the home for engineering or monitoring strategies to be employed.

The absence of this pre-installation data limits the type of evaluation that can be performed. For example, engineering estimates of savings from attic insulation require knowledge of the level and condition of the existing insulation, some assessment of the characteristics of the building envelope and the quantity, type and quality of the insulation installed. For infiltration measures such as caulking and weatherstripping, blower door tests should be conducted before and after the installation. This information is not available from the program databases, and expanding the program infrastructure to collect and verify all of this information would be expensive and beyond the scope of program implementation.

As long as detailed pre-installation data are not collected through the normal program channels and these data are unnecessary for program implementation, they will not be collected unless evaluators make it a priority. To obtain these data, evaluators will need to be brought into the process early enough (sometime *prior to* the start of the implementation for the program year to be evaluated) to be able to design a sample plan.

This lead time would allow the evaluators to ensure that all necessary pre-installation data could be collected for the appropriate subset of program participants.

10.4 Define the Scope of the Sample Plan

Any plan that involves collecting pre-installation data is going to need to be well-defined and limited in scope. Focusing on a limited list of measures to evaluate may be necessary to keep costs within a reasonable level. While savings estimates for some measures have tended to vary considerably from one year to the next with billing analysis, the household savings and savings from some major measures are more consistent and reliable. The results of this analysis in conjunction with the previous two indicate that savings at the household level and from the installation of efficient refrigerators are reasonably stable. Consequently, it may be possible to eliminate this measure.

10.5 Consider Qualitative Methods to Assess Savings from Energy Education

Since it appears that the large sample sizes required to conduct a controlled experiment (several thousand) are likely to be prohibitively expensive, more qualitative approaches could still be employed, similar to those used in the 2001 process evaluation of the program. A survey of program participants could be used to establish the extent to which participants recall the energy education they received, and to elicit open-ended responses about actions they have taken as a result of the energy education. Socially desirable responding is a concern in this context, but techniques such as those proposed by McRae (2002) could be used to mitigate this effect. The results of this research would not be defensible estimates of impacts from energy education, but rather establishing whether there is a basis for believing that such impacts exist.

10.6 Applying the Results of this Evaluation

Ideally, the LIEE savings estimates should be based on savings from typical homes during a typical year. This standard was certainly not met for PY 2002. As discussed at length in other sections of this report, the billing analysis was confounded by the volatility in the energy market during the analysis period. Consequently, we were unable to estimate savings associated with some measures, and the savings for other measures seem to be unusually low in comparison to previous evaluations and other sources.

For some non-weather sensitive electric measures, such as refrigeration and lighting, the PY 2002 results seem to be in a relatively reasonable range. While the model exhibited some instability for the smaller hot water measures and for lighting, the overall results generally fall within, or close to, the range of savings estimated in previous evaluations and supported by independent sources, with one exception noted below. For this reason, we recommend that these savings be used for program reporting and planning purposes. PG&E’s electric DHW savings, however, are unusually low, possibly due to the uncertainty associated with identifying participants with electric water heating.

In contrast, the savings for weather-dependent measures and the package of gas water heating conservation measures are less reliable, and, in some cases, could not be estimated at all. In general, the estimated measures tend to fall well below the levels found in previous evaluations. The gas savings for the package of water heating conservation measures is unusually low in comparison to other studies and the expected range of values. For space heating measures, studies outside of the LIEE program do not provide a useful comparison due to differences in housing stock and weather patterns.

Savings from cooling and heating measures can be highly dependent on behavioral patterns, and the billing data indicate that overall consumption was low during the pre-installation period, most likely as a result of the public requests for reducing energy use during the 2001 Energy Crisis. In effect, our results suggest that the PY 2002 savings for weather-dependent measures can be conceptualized as the program savings achieved *above and beyond* the voluntary conservation motivated by the Energy Crisis.

Another issue with the weather-dependent savings is associated with the limitations of the model. The participating utilities requested that the savings be reported by housing type and by climate zone. The ability to obtain the useful results from the general models is dependent on the large sample size. Applying these results to each climate zone, and each housing type within each climate zone, substantially increases the margin of error for each category. Consequently, the climate-zone specific results should be applied only with the understanding that a high degree of uncertainty is associated with these estimates.

For these reasons, we recommend that the PY 2002 estimated gas savings for space heating measures and the package of water heating conservation measures, and the electric savings for heating and cooling measures, should not be used for common program planning and reporting purposes. Given the many external factors at play during this period, it would not be advisable to eliminate specific weather-dependent or water heating measures found to fail the cost-effectiveness criteria on the basis of the PY 2002 Evaluation results. We also recommend against using climate-zone specific estimates to justify the removal of particular measures in one or more geographic regions.

One obvious solution would be to rely on the results of the previous evaluation for these measures. However, the same challenges encountered in conducting the billing analysis for PY2002, including potential effects from the Energy Crisis, are likely to have also had an unknown effect on the PY2000 and 2001 evaluations. For this reason, we recommend returning to deemed savings for these measures, such as can be found the DEER 2001 Update, until better estimates can be obtained, with the caution that engineering estimates not calibrated to billing history may to overstate savings. This tendency can be counteracted by careful selection of the DEER comparison measure. For example, the DEER report provides savings estimates for two levels of attic insulation, 1) adding R-19 to an uninsulated home and 2) increasing insulation levels from R-11 to R-30. Given the uncertainty surrounding the pre-installation conditions in the home and the high savings associated with adding any insulation to a completely uninsulated home, we recommend applying the savings estimates for the second option. The DEER savings will need to be adjusted to reflect the distribution of the LIEE participants among the climate zones.

10.7 Postpone the Next LIEE Impact Evaluation Until PY 2005

We understand that impact evaluations of the LIEE program are generally conducted semiannually, and the next evaluation would be scheduled for PY 2004. We strongly recommend that the next impact evaluation be postponed at least until PY 2005 for two reasons: to allow the utilities to improve the data collection and to provide additional time for planning the next evaluation.

In the course of conducting this analysis, we had to rely on the data routinely collected through program implementation and discovered that some critical data for impact evaluation were missing. However, since the draft report was provided to the utilities in the third quarter of 2004, the opportunity to take corrective action for PY 2004 has been lost. The other major consideration is that monitoring and engineering strategies will require the evaluators to be involved in the evaluation planning *prior* to the start of the program year under consideration, which is not possible for PY 2004.

Consequently, an impact evaluation conducted for PY 2004 will suffer from the same set of problems encountered in the PY 2002 evaluation. Since it is virtually guaranteed at this point that the evaluators will be brought into the process following the completion of PY 2004, the choices will be limited and a billing analysis is likely to be the only real option. The billing analysis will be hampered by the lack of some critical data. Under these circumstances, the results will be likely to exhibit a high degree of uncertainty, and the value of conducting such an exercise is questionable.

Should the parties decide to conduct an impact evaluation for PY 2005, the evaluation planning should commence as soon as possible.

10.8 Conclusion

Improved data collection will be necessary for any future evaluations efforts and should be pursued immediately. The next step in preparing for the next evaluation is to define the outstanding questions regarding the measures installed through the LIEE. Billing analysis could be an effective tool for estimating savings at the household level and for some major measures, as long as the additional data listed above in Section 10.1 are incorporated into the regular program data collection process. This approach would not require the extensive lead time needed for engineering or monitoring studies and is likely to cost less, but is unlikely to improve the estimated savings associated with smaller and less frequently-installed measures.

If the primary concern relates to a small number of measures where the results of the billing analysis show substantial variation from year to year, then a reasonable approach is to pursue an engineering or monitoring study. In this case, the evaluators will need to be on board prior to the delivery of services to design the sampling plan and ensure that all of the necessary data is collected. The impact evaluation could also include a controlled experiment to estimate the energy savings from the educational component of the program. The higher costs associated with this approach should also be factored into the final decision.

Finally, deemed savings should also be considered as a solution to estimating measure-level savings for this program. This approach is by far the least expensive, and the incremental improvements in measure-level savings offered by the other approaches may not be worth the additional costs.

List of Appendices

Appendix A-1

Regression Output

for the

Final Models

A Appendix A

A.1 Regression Output for the Final Models

The tables below show the regression outputs and bootstrap standard errors for the final models. The variables are defined in Tables 6-1, 6-3, 6-5 and 6-6. The first three tables present the results from the three electric base models, the following two contain the results from the electric cooling models, and the final table consists of the results from the gas model. The definitions of the variables presented in Tables 6.1, 6.3, 6.5 and 6.6 are combined and repeated at the end of this section, for the convenience of the reader.

Table A-1.1: PG&E Base Model

		Regression Results			Bootstrap
Parameter	Estimate	Standard Error	t-value	p-value	Standard Error
Nref	(685)	11.04	(62.10)	<0.001	20.98
Nltgprd	(43)	2.59	(16.54)	<0.001	4.72
Odhw	(104)	21.44	(4.85)	<0.001	50.97
Ishload	168	1.32	127.17	<0.001	6.39
Dpostclg	(7)	3.37	(2.02)	0.043	8.01
Dcare	(34)	8.47	(4.03)	<0.001	15.09
Carepost	(36)	15.22	(2.34)	0.019	27.35
careposthtg	16	1.25	13.14	<0.001	2.31
carepostclg	14	3.69	3.89	<0.001	8.78
Nhdd	27	1.18	23.21	<0.001	2.05
Nhddmf	(55)	1.24	(44.56)	<0.001	2.96
Ncdd	405	1.65	244.82	<0.001	4.88
Ncddmf	7	4.33	1.73	0.084	14.26
R-squared	0.794				
# of accts	29,786				
# of observations	703,985				

Table A-1.2: SCE Base Model

		Regression Results			Bootstrap
Parameter	Estimate	Standard Error	t-value	p-value	Standard Error
Nref	(666)	11.69	(57.00)	<0.001	21.00
Nltgprd	(21)	3.11	(6.71)	<0.001	5.98
Odhw	(261)	33.66	(7.76)	<0.001	71.12
Ishload	44	1.06	41.44	<0.001	3.72
Dcare	(8)	10.04	(0.80)	0.422	17.68
Carepost	(71)	14.63	(4.88)	<0.001	28.24
careposthtg	14	1.48	9.68	<0.001	3.18
carepostclg	46	3.77	12.22	<0.001	16.86
Nhdd	(26)	1.40	(18.22)	<0.001	4.22
Nhddmf	162	1.10	3.87	<0.001	3.20
Ncdd	462	2.72	170.18	<0.001	16.99
Ncddmf	(18)	4.36	(4.02)	<0.001	25.84
R-squared	0.776				
# of accts	15,956				
# of observations	375,693				

Table A-1.3: SDG&E Base Model

		Regression Results			Bootstrap
Parameter	Estimate	Standard Error	t-value	p-value	Standard Error
Nref	(674)	15.13	(44.52)	<0.001	32.01
Nltgprd	(29)	4.56	(6.27)	<0.001	10.33
Odhw	(213)	41.77	(5.10)	<0.001	145.97
Ishload	105	2.09	50.18	<0.001	7.22
Dpostclg	(66)	32.86	(2.00)	0.045	70.86
Dcare	76	15.59	4.90	<0.001	33.53
Carepost	(92)	20.78	(4.41)	<0.001	37.09
Careposthtg	6	3.01	1.87	0.061	4.74
Carepostclg	114	32.27	3.54	<0.001	77.60
Nhdd	63	3.66	17.17	<0.001	5.15
Nhddmf	(85)	2.07	(40.81)	<0.001	5.92
Ncdd	874	24.76	35.29	<0.001	87.54
Ncddmf	(357)	24.80	(14.40)	<0.001	93.00
R-squared	0.850				
# of accts	5,093				
# of observations	120,698				

Table A-1.4: PG&E Cooling Model

		Regression Results			Bootstrap
	Estimate	Standard Error	t-value	p-value	Standard Error
Nbase	(451)	37.71	(11.97)	<0.001	65.08
Nevap	212	43.43	4.88	<0.001	62.41
Ievap	32	9.42	3.39	<0.001	19.63
Ievapm	(223)	11.39	(19.53)	<0.001	23.17
Iac	45	16.20	2.79	0.005	42.36
Ishload	152	4.40	34.56	<0.001	17.34
Dcare	3	21.74	0.13	0.898	36.76
Carepost	143	42.79	3.35	<0.001	65.76
Careposthtg	(22)	3.51	(3.65)	<0.001	4.81
Carepostclg	10	9.03	1.12	0.261	18.81
Nhdd	36	3.50	7.53	<0.001	5.02
Nhddmf	(32)	3.07	(10.28)	<0.001	5.44
Ncdd	518	4.53	114.50	<0.001	12.84
Ncddmf	(174)	8.04	(21.61)	<0.001	21.87
R-squared	0.763				
# of accts	6,971				
# of observations	165,113				

Table A-1.5: SCE Cooling Model

		Regression Results			Bootstrap
	Estimate	Standard Error	t-value	p-value	Standard Error
Nbase	(307)	50.24	(6.11)	<0.001	54.00
Nevap	(453)	138.57	(3.26)	<0.001	204.53
Ievap	35	31.22	1.11	0.268	93.55
Ievapm	(24)	6.74	(3.61)	<0.001	24.08
Iac	(145)	13.76	(10.56)	<0.001	43.31
Ishload	10	2.96	3.23	<0.001	7.31
Dcare	(14)	35.71	(0.40)	0.69	58.47
Carepost	(100)	39.06	(2.56)	0.011	68.32
Careposthtg	36	3.88	(9.29)	<0.001	7.03
Carepostclg	37	7.68	4.78	<0.001	31.47
Nhdd	16	3.16	5.23	<0.001	6.76
Nhddmf	(9)	3.60	(2.61)	0.009	7.37
Ncdd	511	4.31	118.61	<0.001	20.59
Ncddmf	(140)	7.86	(17.85)	<0.001	37.00
R-squared	0.777				
# of accounts	3,425				
# observations	81,000				

Table A-1.6: Gas Model

		Regression Results			Bootstrap
	Estimate	Standard Error	t-value	p-value	Standard Error
iainsul	(8.0)	0.10	(78.14)	<0.001	0.37
Ifurnrep	9.3	0.25	35.67	<0.001	0.64
ihsmnt	4.2	0.27	15.57	<0.001	0.79
iducts	1.2	0.25	4.85	<0.001	0.61
itstat	1.7	0.17	10.40	<0.001	0.40
ishother	(1.5)	0.10	(16.03)	<0.001	0.20
ndhwcons	(4.0)	0.62	(6.51)	<0.001	0.80
ndwhrep	(18.8)	2.06	(9.12)	<0.001	2.50
time01	(13.2)	6.71	(1.96)	0.050	11.08
time02	3.5	6.71	0.52	0.601	11.12
time03	7.0	6.72	1.04	0.297	11.17
dcare	1.3	0.56	2.41	0.016	0.77
carepost	(8.1)	0.68	(11.85)	<0.001	0.96
careposthtg	1.8	0.11	17.13	<0.001	0.25
gasheathdd	45.9	0.10	464.06	<0.001	0.37
gasheathddmf	(30.7)	0.12	(260.26)	<0.001	0.40
R-squared	0.742				
# of accts	56,198				
# of observations	1,379,187				

Table A-1.7: Variables in Both Electric and Gas Models

Variable Name	Interaction	Meaning
Dpost	(not in the final model)	Dummy variable, 0 for the pre period, 1 for the post period; interacted with measure variables to estimate savings and other differences between the pre and post periods; *not included in the final model*
Nhdd		Average daily heating degree days for the period; reflects change in usage associated with colder temperatures
Nhddmf	Nhdd*mf	Same as above for multifamily homes
Dcare		1 if the participant was on the CARE rate for that month, 0 otherwise, reflects impact of the Care rate on usage
Carepost	Dcare*dpost	Change in the usage associated with the CARE rate from pre to post installation periods
Icareposthtg	Dcare*dpost *nhdd	Heating-sensitive post-period CARE impacts

Table A-1.8: Variables in the Electric Model Only

Variable	Interaction	Meaning
Ncdd		Average daily cooling degree days for the period; when multiplied by the average CDD, it reflects the additional (or reduced) usage associated with the increase in temperature
Ncddmf	Ncdd*mf	Same as above for multifamily homes
Icarepostclg	Dcare*dpost *ncdd	Cooling-sensitive post-period CARE impacts
Ishload	Esh*dpost *nhdd	Heating-related variation in usage in homes with electric space heat
Nref	ref*dpost	Estimates refrigerator savings by house
Nltgprd	Ltgprd*dpost	Estimates lighting savings per product
Ndhw	Dhw*dpost	Estimates DHW package savings per homes
Nbase	Base*dpost	Reflects savings associated with lighting or refrigeration measures; not used to estimate savings for these measures
Nevap	Evap*dpost *summo	1 if an evaporative cooler was installed and the read period is during the cooling season (May to September), 0 otherwise; reflects non-weather sensitive seasonal savings for evaporative coolers
Ievap	Evap*dpost *ncdd	Daily CDD during the post-period for homes with evaporative coolers installed; reflects change in usage as temperatures increase
Ievapm	Evapm*dpost *ncdd	Same as above for homes with evaporative cooler maintenance
Iac	AC*dpost *ncdd	Same as above for homes with A/C replacement

Table A-1.9: Variables in the Gas Model Only

Variable	**Interaction**	**Meaning**
Gasheathdd	Gasheat*hdd	Weather-sensitive variable accounts for gas space heat usage
Gasheathddmf	Gasheat*hdd *mf	Same as above for multifamily homes
gasheathddtime	Gasheat*hdd *Time	Reflects change in gas space heating usage over time
Iainsul	Ainsul*hdd *dpost + (existing insul) *hdd	Weather-sensitive savings for homes with attic insulation and gas space heating; models all homes with attic insulation; savings estimated by comparing homes with existing attic insulation to those receiving insulation through the program
Ifurnrep	Furnrep*hdd *dpost	Same as above for homes with furnace replacement
Ihsmnt	Hsmnt*hdd *dpost	Same as above for homes receiving heating system maintenance
Itstat	Tstat**hdd *dpost	Weather-sensitive change in use for homes receiving programmable thermostats and having gas space heating; reflects change in usage as temperatures decrease
Iducts	Ducts*hdd *dpost	Same as above for homes receiving duct repairs and sealing
Ishother	Shother*hdd *dpost	Same as above for homes receiving at least one other envelope or heating system measure
Ndhwcons	Dhwcons *dpost	Dummy variable set to 1 for homes with least one DHW conservation measure and gas water heating, 0 otherwise
Ndhwrep	Dhwrep *dpost	Same as above for homes receiving a new gas DHW tank

Appendix A-2

Alternative Models

A.2 Alternative Models

Three of the many alternatives explored are discussed below:

- Adding a variable to model program effects beyond the effects associated with specific measures
- Bundling water and space heating measures
- Designating homes with existing central air conditioning for estimating the savings from cooling measures

Program Effects

The analysis of program effects is provided in Section 7.5.7 of the main report. Table A-2.1 below shows the regression output for the alternative runs with the program effects.

Table A-2.1: Program Effects

	PG&E		SCE		SDG&E	
	Estimate	Regression t-value	Estimate	Regression t-value	Estimate	Regression t-value
dpost	-148	-4.78	-108	-4.70	6	0.23
nref	-670	-58.43	-612	-37.30	-675	-39.63
nltgprd	-19	-3.35	-7	-1.70	-29	-5.75
odhw	-104	-4.84	-254	-7.54	-213	-5.10
ishload	168	127.17	44	41.24	105	50.18
dpostclg	-5	-1.40			-67	-2.02
dcare	-38	-4.50	-14	-1.42	77	4.86
carepost	-14	-0.91	-32	-1.90	-94	-4.07
careposthtg	16	13.10	15	9.87	6	1.87
carepostclg	13	3.39	46	12.24	115	3.54
nhdd	27	23.20	-26	-18.35	63	17.17
nhddmf	404	244.43	462	170.19	874	35.25
ncdd	-55	-44.54	4	3.85	-84	-40.81
ncddmf	8	1.78	-18	-4.05	-357	-14.40
R-squared	0.794		0.776		0.850	
# of accounts	29,786		15,956		5,093	

Bundling Space and Water Heating Measures

Table A-2.2 below shows that the vast majority of homes with electric water heaters also have electric space heating. Overall, energy usage associated with electric space heating increased in the post-installation period, masking the impact of the measures designed to save energy used for space heating.

Table A-2.2: Coincidence of Electric Water and Space Heating[44]

Homes with Electric DHW Measures	PGE	SCE	SDG&E	Totals
# with electric space heat conservation	1,166	314	134	1,614
# with electric space heat	1,248	314	135	1,697
Total	1,627	314	155	2,096

Due to the high coincidence of electric space and water heating, this effect also made it difficult to estimate the savings from electric DHW conservation measures. Three scenarios were considered to address this issue:

A) model water and space heating measures separately,
B) bundle water and space heating measures together, and
C) model DHW conservation measures only with an added variable to account for the variations related to space heating load.

The results of these three options are summarized below.

Table A-2.3: Comparison of DHW Alternative Models (Combined Utilities)

Scenario	Annual Savings (kWh) A	Annual Savings (kWh) B	Annual Savings (kWh) C
Refrigerator	700	706	698
Lighting	24	24	24
DHW Conservation Measures	706	Not modeled	153
Space Heating Conservation Measures	(628)	Not modeled	Not modeled
Combined Water & Space Heating	Not modeled	46	Not modeled
R-squared	0.795	0.794	0.794

In the first scenario, the savings associated with the electric DHW conservation measures are unrealistically high, and the space heating conservation measures appear to be creating additional use. These negative savings are likely to be a result of the higher energy use for electric space heating across the board. When space and water heating

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[44] This table is based on the homes identified with electric water and/or space heating by the utility designators.

measures are combined, the bundled savings are low, most likely due to the overwhelming impact of the increase in space heating usage. The third scenario, i.e., the final model used for each utility, accounts for variations due to the space heating load and results in a more reasonable estimate of actual impacts from DHW conservation measures.

Existing Air Conditioners

PG&E and SCE maintain a record of the existing air conditioners at each home in their tracking systems. PG&E's program database has a field that marks the presence of central air conditioning and whether it is functional. SCE records the presence of central and wall air conditioners and evaporative coolers, but no indication of the condition of this cooling equipment. Since the program protocols indicate that nonfunctional equipment may be replaced, the issue remains whether higher savings can be identified in homes known to have functional cooling equipment prior to the installation.

The tables below show the number of homes with cooling equipment for PG&E. Many homes are marked as not having a central air conditioning unit, having a nonfunctional unit or the information is missing. Particularly for evaporative cooler installations, the presence of existing cooling equipment is unknown for a high proportion of homes. It is important to note that the absence of central air conditioning does not necessary indicate the absence of other cooling equipment.

Table A-2.4: Number of Homes with Existing Central Air Conditioning (PG&E)

	Measures Installed			
Existing Central Air	Evap Cooler Installs	Evap Cooler Maintenance	A/C Replacement	Total in Sample
Yes	2,666	64	154	6,505
No	902	373	4	11,324
Nonfunctional	37	11	24	341
Unknown	1,856	0	1	10,539
Total # of homes	5,461	448	183	28,709

The PG&E cooling model was run only for homes with existing, functional central air conditioners. These results, shown in Table A-2.5, indicate an increase in use for evaporative coolers, lower savings for evaporative cooler maintenance (in comparison to the full model) and small savings for air conditioner replacements. These results have not been check through the bootstrap analysis, and it is possible, even likely, that the air conditioner savings may not be statistically significant when the bootstrap standard errors are calculated.

Table A-2.5: PG&E Cooling Model for Homes with Central A/C

		Regression Results		
	Estimate	Standard Error	t-value	p-value
Nbase	(552)	58.55	(9.43)	<0001
Nevap	545	61.48	8.86	<0001
Ievap	16	14.33	1.11	0.268
Ievapm	(116)	24.31	(4.78)	<0.001
Iac	(51)	19.27	(2.63)	0.009
Ishload	154	4.90	31.49	<0.001
Dcare	23	29.33	0.77	0.443
Carepost	180	69.46	2.59	0.010
Careposthtg	(38)	5.10	(7.53)	<0001
Carepostclg	15	13.99	1.09	0.278
Nhdd	24	4.52	5.34	<0.001
Nhddmf	(38)	3.81	(9.91)	<0.001
ncdd	595	5.77	103.19	<0.001
ncddmf	(232)	9.41	(24.64)	<0.001
R-squared	0.771			
# of accts	3,991			

Table A-2.6 shows the distribution of cooling equipment for SCE's participants. In the SCE data set, it was not possible to distinguish between nonfunctional and operational equipment. Given this limitation and the high proportion of homes with existing cooling equipment, no further analysis was conducted.

Table A-2.6: Number of Homes with Existing Air Conditioning (SCE)

	Measures Installed			
	Evap Cooler Installs	Evap Cooler Maint	A/C Replace	Total in Sample
Existing Central or Wall A/C				
Yes	113	1,483	870	5,952
No	1	258	63	9,105
Unknown	0	0	0	16
Total	114	1,741	933	15,073

Gas Water Heating Savings

Savings from water heating conservation measures are somewhat unstable in the model. The values for the DHW package savings fluctuate depending on the presence of the term representing the change in use associated with the CARE rate during the post period. When the care/post variable is removed from the gas model, the DHW savings increase by almost double. This result could be an indication that the efficiency improvements for DHW are showing up in the care/post variable.

The SAS output from the final model and the alternative run are given in Table 2. Scenario 1 is the final model as described in the report. Scenario 2 shows the impact of removing the care/post variable. The variable "ndhwcons" (in italics) represents the savings from DHW conservation measures.

Table A.2-7: Comparison of Gas Models

Variable	**Measure Estimated**	**Scenario 1**	**Scenario 2**
Iainsul	Attic insulation	(8.0)	(8.0)
Ifurnrep	Furnace replacement	9.3	9.2
Ihsmnt	Furnace repair	4.2	4.2
Iducts	Duct repair & sealing	1.2	1.3
Itstat	Prog. Thermostats	1.7	1.8
Ishother	Other space heating	(1.5)	(1.3)
Ndhwcons	*DHW conservation*	*(4.0)*	*(7.9)*
Ndwhrep	DHW replacement	(18.8)	(19.9)
time01		(13.2)	(13.7)
time02		3.5	2.1
time03		7.0	5.0
Dcare		1.3	(0.6)
Carepost		(8.1)	
careposthtg		1.8	1.3
gasheathdd		45.9	46.0
gasheathddmf		(30.7)	(30.7)
R-squared		0.742	0.742
# of accts		56,198	56,198

Appendix A-3

Pre/Post

Sample Selection

A.3 Pre/Post Sample Selection

The supplementary materials provided in this appendix are intended to provide additional detail regarding the process of selecting the sample for the simple pre/post analysis. In the initial step, the control group sample was selected to match the treatment group by utility, housing type, usage level. The second stage consisted of ensuring that the pre/post periods for the two groups were also consistent.

Utility, Housing Type and Usage Level

The three electric utilities are included in the electric model, SCE, PG&E and SDG&E and the gas model is comprised of participants with gas accounts and space or water heating measures in the territories served by SoCalGas, PG&E and SDG&E.

The housing type designations are the same as provided by the utilities, i.e., multifamily, mobile homes and single family. Due to the large proportion of 2002 PG&E participants with no housing type designation, the housing type is omitted from the PG&E control group selection. SolCalGas also designates “condos” as a separate housing type; in our analysis, these homes are counted as multifamily units.

For the electric model, the 2002 participants were assigned to five usage categories based on their daily kWh use during the pre-installation period. The usage categories are based on the distribution of electric usage of the treatment group. For the electric model, the usage bins were defined by utility and single family versus multifamily housing. The “very low” group was defined as the usage range of the lowest 25% of the treatment group, the “low” range from the second quartile and the “medium” range from the third quartile. The “high” and “very high” together comprise the highest 25%, with the “very high” range determined from the highest 10%.

For the gas model, one set of usage categories were developed for all participants, also based on quartiles of the treatment group. The usage levels are listed in Table A-3.1 below.

Table A-3.1: Usage Categories

	Utility	SCE	SCE	SDGE	SDGE	PGE	All Gas
	Housing Type	MF	SF	MF	SF	ALL	ALL
	Fuel Type	Elec	Elec	Elec	Elec	Elec	Gas
	Units	KWh/yr	kWh/yr	kWh/yr	KWh/yr	KWh/yr	Therms/yr
	Usage Levels	Up to	Up to	Up to	Up to	Up to	Up to
1	Very Low	2,322	3,161	2,045	2,896	3,061	259
2	Low	3,225	4,502	2,830	4,134	4,611	379
3	Medium	4,538	6,343	3,915	6,064	6,803	524
4	High	6,267	8,640	5,254	8,402	9,422	>525
5	Very High	> 6,267	> 8,640	> 5,254	> 8,402	>9,422	
	N	12,776	11,339	5,701	4,307	37,341	42,129

A random number was assigned to each member of the control group and the file was sorted by utility, house type, usage level and random number. The frequencies for the treatment group were counted by utility, house type and usage level, and the control group was selected to match the proportions of the treatment group in each category.

Time Periods

The treatment and control groups were compared on the basis of the ending month and year of the post-installation period. For the control group, the end of the potential billing (post-installation) period ends in the month prior to the first installation. The end of the post installation period of the treatment group was assigned to be one year following the final installation.

Many of the 2002 participants received measures that were installed at different times, creating a gap between the first and last installation dates. Consequently, there is also a corresponding interval between the pre- and post-installation periods. To account for this pattern, all of the control group members were assumed to have a four-month gap between the end of the pre-installation period and the beginning of the post-installation. For the treatment group, this assumption was also used to calculate pre/post usage for participants who received all measures within the four-month period (over 97% of the treatment group.) The pre and post installation periods for the small remaining group (less than 3%) with an unusually wide gap between installations were determined from the actual installation dates.

The frequencies in the treatment group by usage level and end of post installation period were calculated and used to set the target sample size in each usage/date category for the control group.

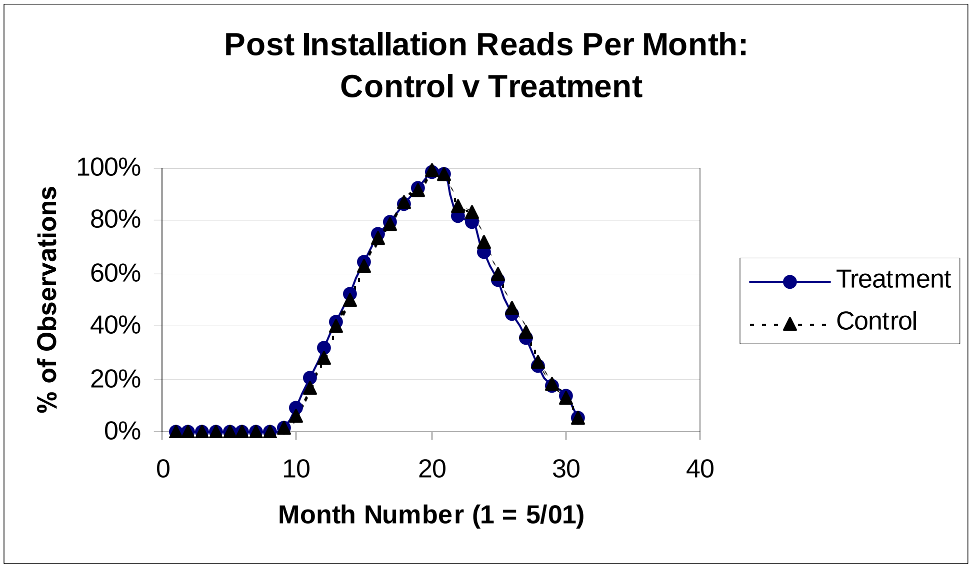
Sample Selection

Each potential control group participant was selected first by the utility/house type/usage categories and then checked against the usage level/time period targets. If it was not possible to fill all of the first level categories and still meet the time period requirements, then the control group members were re-evaluated and, if the potential control group member had an end date *after* the treatment time period to be filled, the control end date was re-assigned to the treatment end date. Using this method, a control group was selected that matched both sets of criteria.

Checking for Validity

The final step was to verify that the process worked correctly. As discussed earlier, the pre-installation usage of the control and treatment groups were compared, and are generally within 5%. The average number of days in the pre period for the control and treatment groups was calculated, and generally match up within one day. The same process was used for the post-installation period, most frequently resulting in the same number of days. Also, the frequency of pre and post installation reads in each month and year were counted and compared as shown in the graph below for the overall household savings. As can be seen from the graph, the pattern of pre-installation reads matches very closely.

Figure A-3.1: Analysis of Post-Installation Reads per Month for Electric Use



Appendix A-4

Analysis of Outliers

A.4 Analysis of Outliers

A description of the methodology to assess the impact of outliers is presented in Chapter 6, Section 6.5.1. One row is devoted to each variable in the analysis, and the final two rows give the R-squared value and the number of accounts in each scenario. The column definitions are given below:

Column A	This column is provided for comparison and includes all observations.
Column B	This is the first DFits scenario, in which homes with an average value of DFits above the size-adjusted cut off are removed from the analysis.
Column C	The second DFits scenario is presented in this column. Homes with 25% of more of the observations exceeding the size-adjusted cut off are removed from the analysis.
Column D	The parameter estimates based on the DFBeta analysis are presented here for the estimates used to calculate measure savings. Please note that the DFBeta analysis was conducted separately for each variable. Thus, a different set of outliers was removed for each variable and the impacts on the other variables are not evaluated.
Column E	This column gives the number of accounts removed for each of the DFBeta results.
Column F	In this scenario, the outliers are weighted to reduce their influence, as described in Chapter 6. This approach is applied only to the SCE cooling model.

Table A-4.1: Outlier Analysis for the PG&E Cooling Model

Column	A All Estimate	B Dfits 1 Estimate	C Dfits 2 Estimate	D DFBeta Estimate	E Accounts Removed
Nbase	(451)	(470)	(485)		
Nevap	212	196	193	254	14
Ievap	32	36	37	3	54
Ievapm	(223)	(209)	(202)	(262)	34
Iac	45	48	45	76	67
Ishload	152	133	109		
Dcare	3	9	3		
Carepost	143	135	136		
Careposthtg	(22)	(19)	(17)		
Carepostclg	10	9	16		
Nhdd	36	21	17		
Nhddmf	(32)	(27)	(26)		
Ncdd	518	492	468		
Ncddmf	(174)	(163)	(170)		
R-squared	0.763	0.734	0.733		
# of accounts	6,971	6,806	6,569		

Table A-4.2: Outlier Analysis for the SCE Cooling Model

Column	A All Estimate	B Dfits 1 Estimate	C Dfits 2 Estimate	D DFBeta Estimate	E Accounts Removed	F Weighted Estimate
Nbase	(307)	(265)	(296)			(301)
Nevap	(453)	(221)	(206)	(285)	11	(357)
Ievap	35	(140)	(93)	(127)	29	(18)
Ievapm	(24)	(40)	(33)	(58)	100	(39)
Iac	(145)	(144)	(96)	(160)	37	(134)
Ishload	10	10	7			8
Dcare	(14)	24	37			(9)
Carepost	(100)	(151)	(70)			(93)
Careposthtg	36	37	30			33
Carepostclg	37	65	30			53
Nhdd	16	10	18			15
Nhddmf	(9)	(11)	(22)			(14)
Ncdd	511	463	492			484
Ncddmf	(140)	(144)	(176)			(151)
R-squared	0.777	0.756	0.765			0.782
# of accounts	3,425	3,326	3,136			3,425

Table A-4.3: Outlier Analysis for the PG&E Base Model

Column	A All Estimate	B Dfits 1 Estimate	C Dfits 2 Estimate	D DFBeta Estimate	E Accounts Removed
Nref	(685)	(686)	(686)	(670)	193
Nltgprd	(43)	(39)	(38)	(39)	138
Odhw	(104)	(105)	(79)	(109)	268
Ishload	168	130	118		
Dpostclg	(7)	(-4)	7		
Dcare	(34)	(23)	(34)		
Carepost	(36)	(42)	(25)		
careposthtg	16	14	11		
carepostclg	14	13	8		
Nhdd	28	22	19		
Nhddmf	(55)	(41)	(38)		
Ncdd	405	378	358		
Ncddmf	7	9	(1)		
R-squared	0.794	0.756	0.753		
# of accounts	29,786	28,947	28,044		

Table A-4.4: Outlier Analysis for the SCE Base Model

Column	A All Estimate	B Dfits 1 Estimate	C Dfits 2 Estimate	D DFBeta Estimate	E Accounts Removed
nref	(666)	(653)	(645)	(649)	69
nltgprd	(21)	(20)	(19)	(20)	94
odhw	(261)	(251)	(134)	(252)	103
ishload	44	38	32		
dcare	(8)	(7)	1		
carepost	(71)	(95)	(103)		
careposthtg	14	15	13		
carepostclg	46	69	84		
nhdd	(26)	(20)	(11)		
nhddmf	162	0	(5)		
ncdd	462	461	469		
ncddmf	(18)	(48)	(18)		
R-squared	0.776	0.749	0.751		
# of accounts	15,956	15,411	14,810		

Table A-4.5: Outlier Analysis for the SDG&E Base Model

Column	A All Estimate	B Dfits 1 Estimate	C Dfits 2 Estimate	D DFBeta Estimate	E Accounts Removed
nref	(674)	(662)	(644)	(654)	33
nltgprd	(29)	(34)	(33)	(28)	46
odhw	(213)	(343)	(180)	(163)	64
ishload	105	102	91		
dpostclg	(66)	(60)	(46)		
dcare	76	69	71		
carepost	(92)	(90)	(124)		
careposthtg	6	8	11		
carepostclg	114	29	24		
nhdd	63	57	49		
nhddmf	(85)	(77)	(65)		
ncdd	874	697	660		
ncddmf	(357)	(147)	(127)		
R-squared	0.850	0.803	0.796		
# of accounts	5,093	4,973	4,831		

Appendix A-5

Attrition by House Type

A.5 Attrition by House Type

The process for eliminating participants from the final account-level sample is described in Chapter 7, Section 7.3 of the main report. Tables A-5.1 and A.5.2 shows the attrition by house type for the electric and gas models, respectively.

Table A-5.1: Attrition from the Electric Model by House Type

	Total	Multi-Family	Mobile Homes	Single Family	Unknown
Total Premises with Electric Measures	118,309	35,006	9,111	51,247	22,945
Reason for Elimination					
Master-metered/C&I Rates	15,516	3,089	5,270	3,128	4,029
No History	25,913	6,643	1,457	13,840	3,973
Insufficient pre/post	3,964	1,553	104	1,589	718
Out of date range/other	6,066	2,736	112	2,559	659
Premises Available	66,850	20,985	2,168	30,131	13,566
Percent of Total	57%	60%	24%	59%	59%
Insufficient Account Pre/post	18,975	8,727	438	6,780	3,030
Accounts Sample Size	47,872	12,258	1,727	23,351	10,536
Percent of Available Premises	72%	59%	80%	78%	78%

Table A-5.2: Attrition from the Gas Model by House Type

	Total	Multi-Family	Mobile Homes	Single Family	Unknown
Total Premises with Gas Measures	71,050	25,918	3,056	41,948	128
Reason for Elimination					
Master-metered/C&I Rates	1,857	583	804	465	5
No History	11	6	1	3	1
Insufficient pre/post	10,102	5,833	155	4,100	14
Out of date range/other	5,783	1,649	327	3,807	0
Premises Available	53,297	17,847	1,769	33,573	108
Percent of Total	75%	69%	58%	80%	84%
Insufficient Account Pre/post	9,638	6,303	374	2,938	23
Accounts Sample Size	43,659	11,544	1,395	30,635	85
Percent of Available Premises	82%	65%	79%	91%	79%

Appendix B

Results by Climate Zone and House Type

Table B-1: Pacific Gas & Electric

			Unit Savings		**Units Installed**		**Total Savings**	
Measure	**House Type**	**Climate Zone**	**Elec AC**	**Gas SH**	**Elec AC**	**Gas SH**	**Elec AC**	**Gas SH**
Attic Insulation	MF	2		-		1		-
Attic Insulation	MF	3		20.0		22		440
Attic Insulation	MF	4		21.9		30		657
Attic Insulation	MF	5		44.3		-		-
Attic Insulation	MF	12		19.5		31		604
Attic Insulation	MF	13		17.2		43		738
Attic Insulation	MH	3		-		2		-
Attic Insulation	MH	11		-		1		-
Attic Insulation	SF	1		85.4		37		3,158
Attic Insulation	SF	2		58.8		80		4,703
Attic Insulation	SF	3		49.5		1,063		52,640
Attic Insulation	SF	4		44.3		726		32,137
Attic Insulation	SF	11		56.3		191		10,755
Attic Insulation	SF	12		48.2		887		42,785
Attic Insulation	SF	13		42.6		866		36,903
Attic Insulation	SF	16		46.4		4		186
Caulking	MF	1		1.3		68		87
Caulking	MF	2		0.6		271		160
Caulking	MF	3		0.7		1,311		878
Caulking	MF	4		-		173		-
Caulking	MF	5		1.1		1		1
Caulking	MF	9		-		1		-
Caulking	MF	11		0.6		228		146
Caulking	MF	12		0.7		2,092		1,490
Caulking	MF	13		0.9		1,074		918
Caulking	MH	1		1.3		75		96
Caulking	MH	2		1.1		115		129
Caulking	MH	3		-		163		-
Caulking	MH	4		-		61		-

Table B-1: continued

PGE **Measure**	**House Type**	**Climate Zone**	**Unit Savings** **Elec AC**	 **Gas SH**	**Units Installed** **Elec AC**	 **Gas SH**	**Total Savings** **Elec AC**	 **Gas SH**
Caulking	MH	11		0.9		343		304
Caulking	MH	12		0.8		731		618
Caulking	MH	13		0.9		241		216
Caulking	MH	16		0.9		5		4
Caulking	SF	1		1.2		388		480
Caulking	SF	2		1.1		519		578
Caulking	SF	3		1.0		3,807		3,665
Caulking	SF	4		1.1		1,689		1,878
Caulking	SF	5		-		1		-
Caulking	SF	11		0.9		1,407		1,267
Caulking	SF	12		0.8		5,919		4,913
Caulking	SF	13		0.9		5,165		4,488
Caulking	SF	16		0.9		17		15
Envelope Repair	MF	1		4.8		52		248
Envelope Repair	MF	2		2.3		148		345
Envelope Repair	MF	3		2.6		912		2,381
Envelope Repair	MF	4		1.7		161		267
Envelope Repair	MF	5		6.7		-		-
Envelope Repair	MF	11		1.8		153		268
Envelope Repair	MF	12		2.8		1,538		4,339
Envelope Repair	MF	13		3.2		1,124		3,644
Envelope Repair	MH	1		7.4		69		510
Envelope Repair	MH	2		5.2		108		562
Envelope Repair	MH	3		-		90		-
Envelope Repair	MH	4		-		45		-
Envelope Repair	MH	11		5.0		279		1,405
Envelope Repair	MH	12		4.6		571		2,633
Envelope Repair	MH	13		4.5		221		996
Envelope Repair	MH	16		4.2		5		21
Envelope Repair	SF	1		9.6		360		3,457
Envelope Repair	SF	2		6.7		449		2,994
Envelope Repair	SF	3		6.6		3,458		22,781
Envelope Repair	SF	4		6.7		1,594		10,670
Envelope Repair	SF	5		-		1		-
Envelope Repair	SF	11		5.8		1,302		7,560
Envelope Repair	SF	12		5.8		5,444		31,603

Table B-1: continued

PGE			**Unit Savings**		**Units Installed**		**Total Savings**	
Measure	**House Type**	**Climate Zone**	**Elec AC**	**Gas SH**	**Elec AC**	**Gas SH**	**Elec AC**	**Gas SH**
Envelope Repair	SF	13		5.7		5,932		33,684
Envelope Repair	SF	16		5.5		17		94
Evap Cooler Cover	MF	2		-		2		-
Evap Cooler Cover	MF	3		-		1		-
Evap Cooler Cover	MF	4		0.3		3		1
Evap Cooler Cover	MF	5		0.8		-		-
Evap Cooler Cover	MF	11		0.3		25		9
Evap Cooler Cover	MF	12		0.3		95		32
Evap Cooler Cover	MF	13		0.3		25		6
Evap Cooler Cover	MH	1		-		1		-
Evap Cooler Cover	MH	2		0.8		41		34
Evap Cooler Cover	MH	3		-		10		-
Evap Cooler Cover	MH	4		-		5		-
Evap Cooler Cover	MH	11		0.6		135		85
Evap Cooler Cover	MH	12		0.7		158		104
Evap Cooler Cover	MH	13		0.6		115		74
Evap Cooler Cover	MH	16		0.6		3		2
Evap Cooler Cover	SF	1		-		1		-
Evap Cooler Cover	SF	2		0.8		7		5
Evap Cooler Cover	SF	3		0.8		2		2
Evap Cooler Cover	SF	4		0.8		15		11
Evap Cooler Cover	SF	11		0.6		299		191
Evap Cooler Cover	SF	12		0.7		582		386
Evap Cooler Cover	SF	13		0.6		1,247		797
Evap Cooler Cover	SF	16		0.6		3		2
Furnace Filters	MF	1		2.6		5		13
Furnace Filters	MF	2		1.5		57		83
Furnace Filters	MF	3		1.6		321		512
Furnace Filters	MF	4		1.1		59		66
Furnace Filters	MF	5		3.4		-		-
Furnace Filters	MF	9		-		1		-
Furnace Filters	MF	11		1.2		86		100
Furnace Filters	MF	12		1.6		853		1,386
Furnace Filters	MF	13		1.7		1,154		1,957
Furnace Filters	MH	1		5.1		62		318

Table B-1: continued

PGE			**Unit Savings**		**Units Installed**		**Total Savings**	
Measure	**House Type**	**Climate Zone**	**Elec AC**	**Gas SH**	**Elec AC**	**Gas SH**	**Elec AC**	**Gas SH**
Furnace Filters	MH	2		3.9		91		352
Furnace Filters	MH	3		-		120		-
Furnace Filters	MH	4		-		58		-
Furnace Filters	MH	11		2.6		282		747
Furnace Filters	MH	12		2.8		638		1,813
Furnace Filters	MH	13		2.7		228		612
Furnace Filters	MH	16		2.7		2		5
Furnace Filters	SF	1		5.1		117		601
Furnace Filters	SF	2		3.6		208		752
Furnace Filters	SF	3		3.6		1,430		5,173
Furnace Filters	SF	4		3.4		990		3,351
Furnace Filters	SF	11		3.0		743		2,225
Furnace Filters	SF	12		3.0		3,697		11,107
Furnace Filters	SF	13		2.6		4,064		10,505
Furnace Filters	SF	16		2.7		7		19
Misc. Envelope	MF	1		-		68		-
Misc. Envelope	MF	2		-		303		-
Misc. Envelope	MF	3		-		1,228		-
Misc. Envelope	MF	4		-		170		-
Misc. Envelope	MF	5		0.3		1		0
Misc. Envelope	MF	9		-		1		-
Misc. Envelope	MF	11		-		191		-
Misc. Envelope	MF	12		-		2,050		-
Misc. Envelope	MF	13		-		1,082		-
Misc. Envelope	MH	1		0.6		74		48
Misc. Envelope	MH	2		0.4		115		48
Misc. Envelope	MH	3		-		159		-
Misc. Envelope	MH	4		-		60		-
Misc. Envelope	MH	11		0.3		332		90
Misc. Envelope	MH	12		0.4		708		249
Misc. Envelope	MH	13		0.3		235		63
Misc. Envelope	MH	16		0.3		5		1
Misc. Envelope	SF	1		0.6		369		228
Misc. Envelope	SF	2		0.4		511		194
Misc. Envelope	SF	3		0.4		3,712		1,344

Table B-1: continued

PGE			**Unit Savings**		**Units Installed**		**Total Savings**	
Measure	**House Type**	**Climate Zone**	**Elec AC**	**Gas SH**	**Elec AC**	**Gas SH**	**Elec AC**	**Gas SH**
Misc. Envelope	SF	4		0.3		1,664		564
Misc. Envelope	SF	5		-		2		-
Misc. Envelope	SF	11		0.3		1,381		422
Misc. Envelope	SF	12		0.4		5,764		2,224
Misc. Envelope	SF	13		0.3		5,173		1,346
Misc. Envelope	SF	16		0.3		17		5
Weatherstripping	MF	1		2.6		63		162
Weatherstripping	MF	2		1.6		203		333
Weatherstripping	MF	3		1.6		1,176		1,831
Weatherstripping	MF	4		1.1		171		192
Weatherstripping	MF	5		3.4		1		3
Weatherstripping	MF	11		1.3		188		242
Weatherstripping	MF	12		1.5		1,909		2,940
Weatherstripping	MF	13		1.7		1,037		1,772
Weatherstripping	MH	1		5.1		71		365
Weatherstripping	MH	2		3.8		108		410
Weatherstripping	MH	3		-		154		-
Weatherstripping	MH	4		-		61		-
Weatherstripping	MH	11		2.7		319		854
Weatherstripping	MH	12		2.9		709		2,040
Weatherstripping	MH	13		2.7		231		620
Weatherstripping	MH	16		2.7		5		13
Weatherstripping	SF	1		4.9		386		1,902
Weatherstripping	SF	2		3.6		513		1,857
Weatherstripping	SF	3		3.6		3,795		13,703
Weatherstripping	SF	4		3.4		1,694		5,743
Weatherstripping	SF	5		-		2		-
Weatherstripping	SF	11		2.9		1,409		4,048
Weatherstripping	SF	12		3.0		5,868		17,754
Weatherstripping	SF	13		2.6		5,176		13,497
Weatherstripping	SF	16		2.7		15		40
Evap Cooler Maint	MF	2	43		4		174	
Evap Cooler Maint	MF	11	240		2		480	
Evap Cooler Maint	MF	13	383		14		5,362	
Evap Cooler Maint	MH	2	62		8		496	

Table B-1: continued

PGE			**Unit Savings**		**Units Installed**		**Total Savings**	
Measure	**House Type**	**Climate Zone**	**Elec AC**	**Gas SH**	**Elec AC**	**Gas SH**	**Elec AC**	**Gas SH**
Evap Cooler Maint	MH	11	306		32		9,794	
Evap Cooler Maint	MH	12	547		4		2,188	
Evap Cooler Maint	MH	13	559		22		12,291	
Evap Cooler Maint	MH	16	393		3		1,179	
Evap Cooler Maint	SF	2	62		13		806	
Evap Cooler Maint	SF	11	343		87		29,822	
Evap Cooler Maint	SF	12	246		40		9,833	
Evap Cooler Maint	SF	13	554		560		310,114	
Evap Cooler Maint	SF	16	393		7		2,751	

Table B-2: Southern California Gas

SoCalGas			**Unit Savings**		**Units Installed**		**Total Savings**	
Measure	**House Type**	**Climate Zone**	**Elec AC**	**Gas SH**	**Elec AC**	**Gas SH**	**Elec AC**	**Gas SH**
Attic Insulation	MF	6		13.7		8		109
Attic Insulation	MF	8		9.3		182		1,695
Attic Insulation	MF	9		11.1		24		265
Attic Insulation	MF	10		11.9		12		143
Attic Insulation	MF	16		11.9		5		60
Attic Insulation	SF	6		34.2		14		478
Attic Insulation	SF	8		23.0		269		6,178
Attic Insulation	SF	9		29.0		250		7,243
Attic Insulation	SF	10		29.8		186		5,540
Attic Insulation	SF	13		52.5		8		420
Attic Insulation	SF	14		52.5		1		52
Attic Insulation	SF	15		20.7		6		124
Attic Insulation	SF	16		29.8		34		1,013

Table B-2: continued

SoCalGas			**Unit Savings**		**Units Installed**		**Total Savings**	
	House	**Climate**	**Elec**	**Gas**	**Elec**	**Gas**	**Elec**	**Gas**
Measure	**Type**	**Zone**	**AC**	**SH**	**AC**	**SH**	**AC**	**SH**
Caulking	MF	4		-		4		-
Caulking	MF	6		-		6		-
Caulking	MF	8		-		14		-
Caulking	MF	9		-		10		-
Caulking	MF	10		-		69		-
Caulking	MF	13		0.9		121		113
Caulking	MF	14		-		1		-
Caulking	MF	15		-		1		-
Caulking	MF	16		-		25		-
Caulking	MH	4		-		1		-
Caulking	MH	5		-		1		-
Caulking	MH	6		-		10		-
Caulking	MH	8		1.2		16		19
Caulking	MH	9		1.4		15		21
Caulking	MH	10		1.1		116		132
Caulking	MH	13		0.9		27		24
Caulking	MH	14		1.4		16		22
Caulking	MH	15		1.1		11		13
Caulking	MH	16		1.4		2		3
Caulking	SF	4		-		1		-
Caulking	SF	5		1.1		2		2
Caulking	SF	6		1.1		3		3
Caulking	SF	8		1.1		53		59
Caulking	SF	9		1.2		61		70
Caulking	SF	10		1.1		242		275
Caulking	SF	13		0.9		415		389
Caulking	SF	14		1.3		8		10
Caulking	SF	15		1.0		19		19
Caulking	SF	16		1.2		14		16
Envelope Repair	MF	4		1.7		8		13
Envelope Repair	MF	5		1.3		65		82
Envelope Repair	MF	6		1.6		185		289
Envelope Repair	MF	8		2.1		6,962		14,498
Envelope Repair	MF	9		2.1		5,563		11,453
Envelope Repair	MF	10		1.9		2,181		4,118
Envelope Repair	MF	13		2.6		367		970
Envelope Repair	MF	14		1.4		91		128

Table B-2: continued

SoCalGas **Measure**	**House Type**	**Climate Zone**	**Unit Savings**		**Units Installed**		**Total Savings**	
			Elec AC	**Gas SH**	**Elec AC**	**Gas SH**	**Elec AC**	**Gas SH**
Envelope Repair	MF	15		1.2		252		293
Envelope Repair	MF	16		1.9		171		316
Envelope Repair	MH	4		1.7		1		2
Envelope Repair	MH	5		4.0		24		96
Envelope Repair	MH	6		2.5		42		104
Envelope Repair	MH	8		3.7		36		133
Envelope Repair	MH	9		3.2		55		173
Envelope Repair	MH	10		3.8		133		508
Envelope Repair	MH	13		3.8		31		118
Envelope Repair	MH	14		5.5		57		314
Envelope Repair	MH	15		2.6		31		81
Envelope Repair	MH	16		4.5		6		27
Envelope Repair	SF	4		4.7		18		85
Envelope Repair	SF	5		4.0		242		968
Envelope Repair	SF	6		3.4		194		660
Envelope Repair	SF	8		4.4		5,088		22,226
Envelope Repair	SF	9		4.4		6,503		28,761
Envelope Repair	SF	10		4.6		3,974		18,275
Envelope Repair	SF	12		-		1		-
Envelope Repair	SF	13		4.7		1,396		6,560
Envelope Repair	SF	14		3.7		388		1,444
Envelope Repair	SF	15		3.2		548		1,773
Envelope Repair	SF	16		4.8		424		2,033
Evap Cooler Cover	MF	9		0.2		69		16
Evap Cooler Cover	MF	10		0.1		51		8
Evap Cooler Cover	MF	13		0.3		44		15
Evap Cooler Cover	MF	14		-		1		-
Evap Cooler Cover	MF	16		0.1		10		1
Evap Cooler Cover	MH	4		-		1		-
Evap Cooler Cover	MH	6		-		5		-
Evap Cooler Cover	MH	8		-		16		-
Evap Cooler Cover	MH	9		-		12		-
Evap Cooler Cover	MH	10		0.5		47		21
Evap Cooler Cover	MH	13		0.6		22		14
Evap Cooler Cover	MH	14		1.0		14		13
Evap Cooler Cover	MH	15		0.4		7		3
Evap Cooler Cover	MH	16		-		1		-

Table B-2: continued

SoCalGas **Measure**	**House Type**	**Climate Zone**	**Unit Savings** **Elec AC**	 **Gas SH**	**Units Installed** **Elec AC**	 **Gas SH**	**Total Savings** **Elec AC**	 **Gas SH**
Evap Cooler Cover	SF	6		-		1		-
Evap Cooler Cover	SF	8		0.6		17		10
Evap Cooler Cover	SF	9		0.6		58		35
Evap Cooler Cover	SF	10		0.5		248		113
Evap Cooler Cover	SF	13		0.7		333		224
Evap Cooler Cover	SF	14		0.5		29		15
Evap Cooler Cover	SF	15		0.4		22		9
Evap Cooler Cover	SF	16		0.5		53		24
Misc. Envelope	MF	4		-		20		-
Misc. Envelope	MF	5		-		92		-
Misc. Envelope	MF	6		-		118		-
Misc. Envelope	MF	8		-		4,779		-
Misc. Envelope	MF	9		-		3,557		-
Misc. Envelope	MF	10		-		1,365		-
Misc. Envelope	MF	13		-		252		-
Misc. Envelope	MF	14		-		31		-
Misc. Envelope	MF	15		-		124		-
Misc. Envelope	MF	16		-		136		-
Misc. Envelope	MH	4		-		3		-
Misc. Envelope	MH	5		0.3		53		18
Misc. Envelope	MH	6		-		37		-
Misc. Envelope	MH	8		0.2		40		9
Misc. Envelope	MH	9		0.5		84		38
Misc. Envelope	MH	10		0.2		194		44
Misc. Envelope	MH	13		0.3		31		8
Misc. Envelope	MH	14		0.4		44		19
Misc. Envelope	MH	15		0.2		33		7
Misc. Envelope	MH	16		0.6		11		6
Misc. Envelope	SF	4		0.3		22		7
Misc. Envelope	SF	5		0.3		248		84
Misc. Envelope	SF	6		0.3		115		29
Misc. Envelope	SF	7		-		1		-
Misc. Envelope	SF	8		0.4		3,453		1,227
Misc. Envelope	SF	9		0.4		4,305		1,753
Misc. Envelope	SF	10		0.2		2,775		630

Table B-2: continued

SoCalGas			**Unit Savings**		**Units Installed**		**Total Savings**	
Measure	**House Type**	**Climate Zone**	**Elec AC**	**Gas SH**	**Elec AC**	**Gas SH**	**Elec AC**	**Gas SH**
Misc. Envelope	SF	13		0.3		931		260
Misc. Envelope	SF	14		0.4		262		108
Misc. Envelope	SF	15		0.2		401		78
Misc. Envelope	SF	16		0.3		264		69
Weatherstripping	MF	4		1.1		40		45
Weatherstripping	MF	5		1.1		195		219
Weatherstripping	MF	6		1.1		231		248
Weatherstripping	MF	8		1.1		7,094		7,833
Weatherstripping	MF	9		1.1		5,657		6,264
Weatherstripping	MF	10		1.1		2,363		2,687
Weatherstripping	MF	13		1.9		404		785
Weatherstripping	MF	14		1.3		125		159
Weatherstripping	MF	15		0.9		262		231
Weatherstripping	MF	16		1.1		214		243
Weatherstripping	MH	4		1.1		6		7
Weatherstripping	MH	5		3.4		94		317
Weatherstripping	MH	6		2.4		55		130
Weatherstripping	MH	8		2.3		49		111
Weatherstripping	MH	9		2.3		91		210
Weatherstripping	MH	10		2.3		239		543
Weatherstripping	MH	13		2.7		49		134
Weatherstripping	MH	14		3.8		99		375
Weatherstripping	MH	15		2.0		40		81
Weatherstripping	MH	16		2.8		12		34
Weatherstripping	SF	4		3.4		53		179
Weatherstripping	SF	5		3.4		455		1,535
Weatherstripping	SF	6		2.3		213		482
Weatherstripping	SF	7		-		1		-
Weatherstripping	SF	8		2.2		5,205		11,357
Weatherstripping	SF	9		2.3		6,702		15,160
Weatherstripping	SF	10		2.3		4,183		9,508
Weatherstripping	SF	12		-		1		-
Weatherstripping	SF	13		2.8		1,438		4,056
Weatherstripping	SF	14		2.7		551		1,476
Weatherstripping	SF	15		1.9		567		1,079
Weatherstripping	SF	16		2.4		451		1,060

Table B-3: San Diego Gas & Electric

SDGE			**Unit Savings**		**Units Installed**		**Total Savings**	
Measure	**House Type**	**Climate Zone**	**Elec AC**	**Gas SH**	**Elec** AC	**Gas SH**	**Elec AC**	**Gas SH**
Attic Insulation	MF	7		12.4		6		75
Attic Insulation	SF	7		31.2		303		9,465
Attic Insulation	SF	10		35.6		68		2,423
Caulking	MF	7		-		937		-
Caulking	MF	10		-		292		-
Caulking	MF	14		-		1		-
Caulking	MH	7		1.1		50		56
Caulking	MH	10		1.1		166		183
Caulking	MH	15		1.1		16		18
Caulking	SF	7		1.1		2,077		2,251
Caulking	SF	10		1.1		452		476
Caulking	SF	14		1.1		1		1
Caulking	SF	15		-		1		-
Envelope Repair	MF	7		1.2		971		1,150
Envelope Repair	MF	10		1.1		294		324
Envelope Repair	MF	14		-		1		-
Envelope Repair	MH	7		3.6		53		193
Envelope Repair	MH	10		3.9		181		704
Envelope Repair	MH	15		3.5		16		56
Envelope Repair	SF	7		4.1		2,156		8,824
Envelope Repair	SF	10		4.0		477		1,891
Envelope Repair	SF	14		3.5		1		4
Envelope Repair	SF	15		-		1		-

Table B-3: continued

SDGE			**Unit Savings**		**Units Installed**		**Total Savings**	
Measure	**House Type**	**Climate Zone**	**Elec AC**	**Gas SH**	**Elec** AC	**Gas SH**	**Elec AC**	**Gas SH**
Evap Cooler Cover	MH	7		0.5		6		3
Evap Cooler Cover	MH	10		0.5		17		9
Evap Cooler Cover	MH	15		-		1		-
Misc. Envelope	MF	7		-		705		-
Misc. Envelope	MF	10		-		194		-
Misc. Envelope	MF	14		-		1		-
Misc. Envelope	MH	7		0.2		38		8
Misc. Envelope	MH	10		0.2		119		26
Misc. Envelope	MH	15		-		6		-
Misc. Envelope	SF	7		0.3		1,615		413
Misc. Envelope	SF	10		0.2		231		49
Misc. Envelope	SF	14		0.5		1		0
Weatherstripping	MF	7		0.9		955		907
Weatherstripping	MF	10		0.8		294		248
Weatherstripping	MF	14		-		1		-
Weatherstripping	MH	7		2.2		36		80
Weatherstripping	MH	10		2.2		110		241
Weatherstripping	MH	15		2.2		9		20
Weatherstripping	SF	7		2.2		2,103		4,560
Weatherstripping	SF	10		2.1		463		973
Weatherstripping	SF	14		2.2		1		2
Weatherstripping	SF	15		-		1		-

Table B-4: Southern California Edison

SCE			**Unit Savings**		**Units Installed**		**Total Savings**	
	House	**Climate**	**Elec**	**Gas**	**Elec**	**Gas**	**Elec**	**Gas**
Measure	**Type**	**Zone**	**Cooling**	**SH**	**Cooling**	**SH**	**AC**	**SH**
A/C Replacement	MF	6	5		2		10	
A/C Replacement	MF	8	11		260		2,860	
A/C Replacement	MF	9	49		332		16,412	
A/C Replacement	MF	10	130		1,269		164,727	
A/C Replacement	MF	14	201		14		2,814	
A/C Replacement	MF	15	777		80		62,160	
A/C Replacement	MF	16	139		182		25,298	
A/C Replacement	MH	8	18		23		407	
A/C Replacement	MH	9	90		15		1,350	
A/C Replacement	MH	10	162		3		486	
A/C Replacement	MH	15	1,111		9		9,999	
A/C Replacement	SF	8	16		9		144	
A/C Replacement	SF	9	82		13		1,064	
A/C Replacement	SF	10	179		54		9,639	
A/C Replacement	SF	14	331		21		6,956	
A/C Replacement	SF	15	1,111		10		11,110	
A/C Replacement	SF	16	198		1		198	
Evap Cooler Install	MF	9	337		20		6,740	
Evap Cooler Install	MF	10	354		14		4,956	
Evap Cooler Install	MF	13	364		3		1,092	
Evap Cooler Install	MF	14	371		2		741	
Evap Cooler Install	MF	15	471		9		4,239	
Evap Cooler Install	MH	10	505		7		3,532	
Evap Cooler Install	MH	14	522		5		2,610	
Evap Cooler Install	MH	15	673		2		1,346	
Evap Cooler Install	SF	8	475		1		475	
Evap Cooler Install	SF	9	485		30		14,545	
Evap Cooler Install	SF	10	504		81		40,839	
Evap Cooler Install	SF	13	520		7		3,640	
Evap Cooler Install	SF	14	527		79		41,617	
Evap Cooler Install	SF	15	673		4		2,692	
Evap Cooler Install	SF	16	508		5		2,540	

Table B-4: continued

SCE **Measure**	**House** **Type**	**Climate** **Zone**	**Unit Savings** **Elec** **Cooling**	**Unit Savings** **Gas** **SH**	**Units Installed** **Elec** **Cooling**	**Units Installed** **Gas** **SH**	**Total Savings** **Elec** **AC**	**Total Savings** **Gas** **SH**
Evap Cooler Maint	MF	9	8		23		173	
Evap Cooler Maint	MF	10	15		195		2,943	
Evap Cooler Maint	MF	13	23		5		115	
Evap Cooler Maint	MF	14	31		90		2,763	
Evap Cooler Maint	MF	15	94		126		11,850	
Evap Cooler Maint	MF	16	17		31		527	
Evap Cooler Maint	MH	10	22		67		1,441	
Evap Cooler Maint	MH	13	32		17		544	
Evap Cooler Maint	MH	14	68		44		2,992	
Evap Cooler Maint	MH	15	135		125		16,901	
Evap Cooler Maint	SF	9	10		80		803	
Evap Cooler Maint	SF	10	22		367		8,118	
Evap Cooler Maint	SF	13	32		664		21,248	
Evap Cooler Maint	SF	14	46		373		16,995	
Evap Cooler Maint	SF	15	135		294		39,819	
Evap Cooler Maint	SF	16	24		87		2,088	

Appendix C

M&E Protocols

Tables 6 and 7

Appendix C

C.1 M&E Protocols Table 6

1. Average Use

A comparison of program savings to average use is provided in Table 7-2.

2. Net and Gross Load Impacts

Total gross savings are assumed to be equal to total net savings.

A. Total Gross Load Impacts

Only gross first year energy impacts were estimated. Please refer to Chapters 6 and 7 for a discussion of the modeling issues and interpretation of the results.

Table C-1: Total Gross Electric Savings

			90% Confidence Limits		80% Confidence Limits	
Utility	End Use	Total Savings (kWH/yr)	Lower Bound (kWH/yr)	Upper Bound (kWH/yr)	Lower Bound (kWH/yr)	Upper Bound (kWH/yr)
PG&E	Household	28,212	25,682	30,742	26,237	30,186
	Refrigeration	13,112	12,453	13,771	12,598	13,627
	Lighting	14,414	11,984	16,844	12,517	16,310
	Water Heating	300	60	541	112	488
	Cooling	385	320	451	334	437
SCE	Household					
	Refrigeration	6,540	6,202	6,878	6,276	6,804
	Lighting	1,213	647	1,780	771	1,656
	Water Heating	165	91	239	108	223
	Cooling	8,495	7,749	9,242	7,913	9,078
SDG&E	Household	5,216	4,661	5,771	4,783	5,649
	Refrigeration	4,373	4,032	4,714	4,107	4,639
	Lighting	693	288	1,097	377	1,009
	Water Heating	150	(19)	319	18	282

Table C-2: Total Gross Gas Savings

		90% Confidence Limits		80% Confidence Limits	
	Total Savings (therms/yr)	Bootstrap Lower (therms/yr)	Bootstrap Upper (therms/yr)	Bootstrap Lower (therms/yr)	Bootstrap Upper (therms/yr)
Household	986,889	858,182	1,115,596	886,435	1,087,344
Water Heating	282,151	207,194	357,108	223,648	340,654
Space Heating	704,738	604,339	805,138	626,378	783,099

B. Gross Load Impacts by Designated Unit

The designated unit is a dwelling. Some measures are estimated on a per item basis, as defined in the table. Only gross first year energy impacts were estimated.

Table C-3: Gross Electric Savings by Designated Unit

				90% Confidence Limits		80% Confidence Limits	
Utility	End Use	Unit	Savings per Unit (kWH/yr)	Lower Bound (kWH/yr)	Upper Bound (kWH/yr)	Lower Bound (kWH/yr)	Upper Bound (kWH/yr)
PG&E	Household	dwelling	399	383	416	386	412
	Refrigeration	item	685	651	719	658	712
	Lighting	item	43	36	50	37	49
	Water Heating	dwelling	104	16	143	30	129
	Cooling	dwelling	511	402	567	420	548
SCE	Household	dwelling	286	278	295	280	293
	Refrigeration	item	666	632	700	639	693
	Lighting	item	21	11	31	13	29
	Water Heating	dwelling	259	143	374	169	349
	Cooling	dwelling	112	2	221	26	197
SDG&E	Household	dwelling	370	362	379	363	377
	Refrigeration	item	674	622	726	633	715
	Lighting	item	29	12	46	16	42
	Water Heating	dwelling	331	(26)	452	26	400

Table C-4: Gross Gas Savings by Designated Unit

End Use	Unit	Savings per Unit (therms/yr)	90% Confidence Limits		80% Confidence Limits	
			Lower Bound (therms/yr)	Upper Bound (therms/yr)	Lower Bound (therms/yr)	Upper Bound (therms/yr)
Household	dwelling	12.8	10.9	14.7	11.4	14.3
Water Heating	dwelling	4.7	3.5	6.0	3.7	5.7
Space Heating	dwelling	9.8	8.4	11.2	8.7	10.9

3. Net-to-gross ratios

The net-to-gross ratio for the LIEE program is assumed to be 1, i.e., the net impacts are assumed to be equal to the gross impacts. This assumption is consistent with the California M&E Protocols and is a common approach to estimating impacts for low income programs.

4. Designated Unit Intermediate Data

This analysis did not require the use of intermediate data.

5. Precision

The precision of the estimates is reported under item 2 above. All confidence limits are based on the bootstrapped standard errors, as discussed in Chapter 6, Sections 6.3.4 and 6.5.4.

6. Measure Count Data

Measure counts for the total program and for the regression sample are summarized below.

Table C-5: Measure Counts

Electric		Regression Sample # of Dwellings Treated	Regression Sample # of Items Installed	All Participants # of Dwellings Treated	All Participants # of Items Installed
	Household	47,872		107,620	
	Refrigerators	15,982	15,997	33,806	35,450
	Lighting	38,351	172,963	88,163	416,873
	Water Heating	4,676		4,869	
	Cooling	3,192		5,950	
	Comparison Group	11,732			
Gas					
	Household	43,661		77,003	
	Water Heating	32,180		59,862	
	Space Heating	39,566		72,092	
	Comparison Group	12,633			

Additional measure counts are provided for the program participants in Tables 7-4 to 7-7, for the regression models in Tables 6-2 and 6-4, and in the Chapter 7, Results, Tables 7-13 to 7-22. The comparison group consisted of 2003 participants, and only the billing history prior to the installation of measures through the program was used.

7. Distribution by Climate Zone

The table below shows the distribution of the PY 2002 LIEE participants by CEC forecasting climate zone. A small number of participants could not be match to a climate zone.

Table C-6: Distribution of Participants by Climate Zone

CEC Forecasting Climate Zone	# of Gas Accounts	% of Gas Total	# of Electric Accounts	% of Electric Total
None	496	0.4%	539	0.4%
1	3,961	3.2%	3,964	2.6%
2	7,478	6.0%	7,477	4.9%
3	33,765	27.1%	34,621	22.6%
4	11,522	9.2%	11,523	7.5%
5	14,026	11.3%	14,026	9.1%
6	2,605	2.1%	2,605	1.7%
7	453	0.4%	3,336	2.2%
8	1,459	1.2%	5,463	3.6%
9	18,253	14.6%	28,969	18.9%
10	7,860	6.3%	15,408	10.0%
11	7,445	6.0%	10,108	6.6%
12	1,070	0.9%	1,090	0.7%
13	13,132	10.5%	13,147	8.6%
14	51	0.0%	51	0.0%
15	647	0.5%	657	0.4%
16	451	0.4%	458	0.3%
Total	124,674		153,442	

C.2 M&E Protocols Table 7

1. Overview Information

A. Title

Title: Impact Evaluation of the 2002 California Low Income Energy Efficiency Program

Identification Number: XXX

B. Description

Program Low Income Energy Efficiency Program
Program year: 2002
Program Description: See Chapter 2, Program Description.

C. End Uses

End Uses: space heating, space cooling, and water heating, lighting, refrigeration

D. Methods and Models

The results are based on a pooled, time-series, cross-sectional regression analysis and a simple pre/post analysis. See Chapter 5, Approaches to LIEE Impact Evaluation and Chapter 6, Methods and Analysis, specifically Sections 5.5, 6.2 to 6.4 and 6.6. Appendices A-1 and A-2 provide the regression statistics for the final and alternative models.

E. Participant Definition

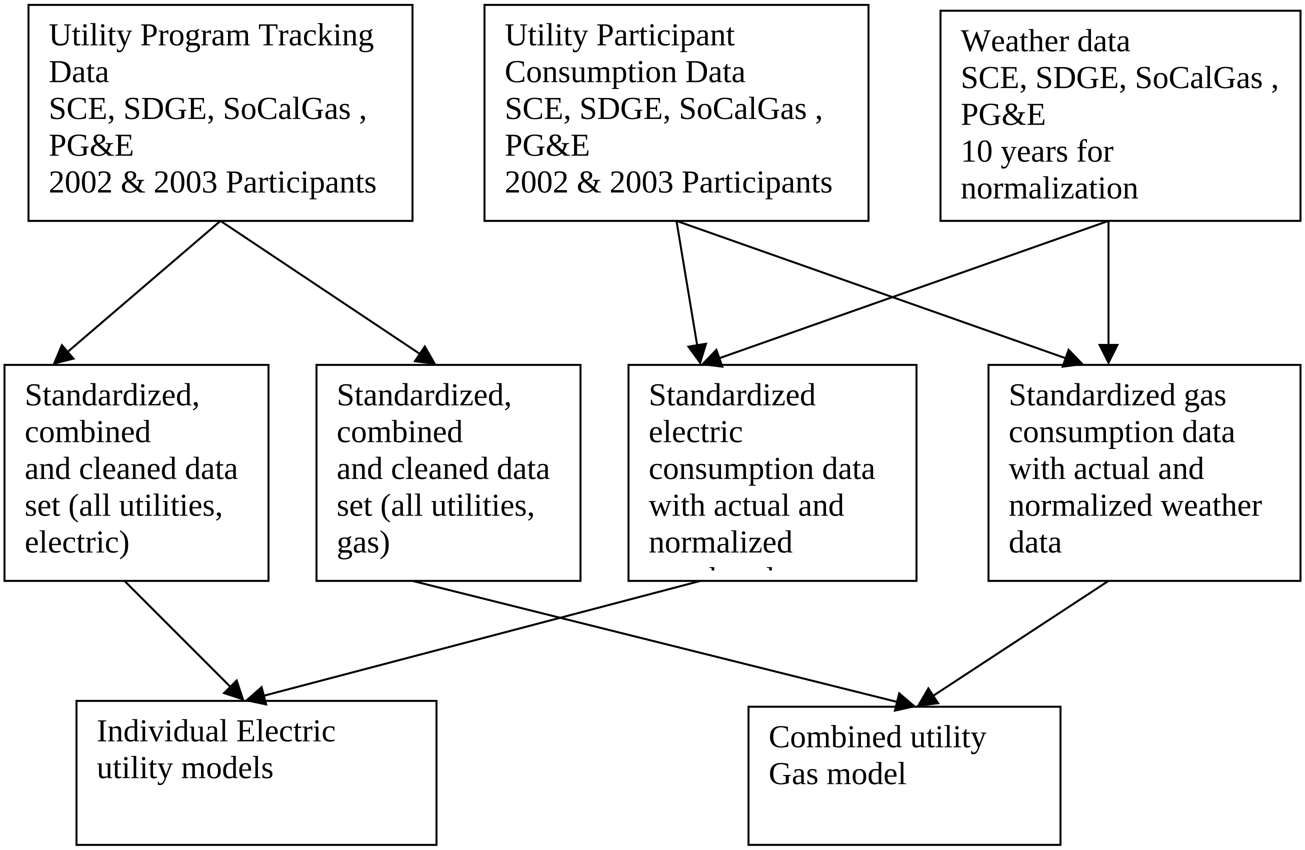
The study defined a participant as a utility account that was associated with a 2002 LIEE participant. The comparison group consisted of utility accounts of 2003 LIEE participants. The billing history for the comparison group covered only the period prior to installing measures through the program.

F. Sample Size

See Tables 6-2, 6-4 and 6-9 for the sample sizes and number of installations. Appendix A-1 contains the details of the final models, including the number of observations.

2. Database Management

A & B. Data Element Flow Chart



C. Attrition

See Chapter 7, Section 7.3, Attrition and Appendix A-5.

D. Data Quality Review

See Chapter 4, Data Collection and Issues.

E. Summary of Data Collected but not Used

Not Applicable.

3. Sampling

A. Sampling Procedures

All participants with sufficient billing history were included in the regression samples. See Chapter 6, Section 6.1.

B. Survey Information

No surveys were conducted.

C. Descriptive Statistics

Table C-7: Descriptive Statistics for the Electric Sample

Variable	Description	N	MIN	MAX	MEAN	STD
nltgprd	Lighting products	1,407,725	0.00	8.00	1.45	2.19
nref	Refrigerator	1,407,725	0.00	1.00	0.13	0.34
odhw	DHW package	1,407,725	0.00	1.00	0.02	0.13
nevap	Evap cooler	1,407,725	0.00	1.00	0.02	0.14
ievap	Evap cooler*ncdd	1,407,725	0.00	18.35	0.07	0.67
ievapm	Evap cooler maint*ncdd	1,407,725	0.00	19.09	0.04	0.59
iac	AC replacement *ncdd	1,407,725	0.00	19.09	0.01	0.21
ishload	Elec space heat load	1,407,725	0.00	32.23	0.97	3.12
DCARE	CARE rate	1,407,725	0.00	1.00	0.69	0.46
carepost	CARE*post period	1,407,725	0.00	1.00	0.32	0.47
careposthtg	CARE*post period*nhdd	1,407,725	0.00	28.75	1.74	3.75
carepostclg	CARE*post period*ncdd	1,407,725	0.00	19.09	0.30	1.35
nhdd	daily hdd	1,407,725	0.00	32.23	5.61	5.44
nhddmf	daily hdd for MF	1,407,725	0.00	31.20	1.46	3.50
ncdd	daily cdd	1,407,725	0.00	19.33	0.93	2.25
ncddmf	daily cdd for MF	1,407,725	0.00	18.70	0.12	0.80
annkwh	kWH per day	1,407,725	0.03	264.00	13.64	9.98

Table C-8: Descriptive Statistics for the Gas Sample

Variable	Description	N	MEAN	STD	MIN	MAX
Iainsul	Attic insulation	1,379,514	3.01	4.54	0.00	32.73
Itstat	Thermostats	1,379,514	0.10	1.02	0.00	20.61
Iducts	Duct repair & sealing	1,379,514	0.04	0.63	0.00	18.63
Ihsmnt	Furance Repair	1,379,514	0.04	0.57	0.00	31.03
Ishother	Other space heating	1,379,514	1.40	3.17	0.00	32.73
Ifurnrep	Furnace replacement	1,379,514	0.06	0.63	0.00	22.24
ndhwcons	DHW conservation	1,379,514	0.28	0.45	0.00	1.00
Ndwhrep	DHW replacement	1,379,514	0.01	0.09	0.00	1.00
dcare	CARE rate	1,379,514	0.62	0.49	0.00	1.00
carepost	CARE/post period	1,379,514	0.28	0.45	0.00	1.00
careposthtg	CARE/post period/hdd	1,379,514	1.19	3.03	0.00	32.19
time01	Read in 2001	1,379,514	0.29	0.45	0.00	1.00
time02	Read in 2002	1,379,514	0.44	0.50	0.00	1.00
time03	Read in 2003	1,379,514	0.27	0.44	0.00	1.00
gasheathdd	daily hdd	1,379,514	4.32	4.78	0.00	32.73
gasheathddmf	daily hdd for MF	1,379,514	1.03	2.75	0.00	24.97
thrm	therms per day	1,379,514	1.10	0.84	0.00	29.00

3. Data Screening and Analysis

A. Outliers, Missing Data and Weather Adjustments

The treatment of outliers is described in Sections 6.3.5 and 6.5.1, and supporting documentation provided in Appendix A-4. Participants with missing data were removed from the analysis. Weather adjustments are discussed in Sections 6.4.2.4 and 6.4.2.6.

B. Addressing Background Effects

A comparison group was included in the analysis to attempt to control for background effects. However, it appears that the analysis results were still affected by the upheaval occurring in the California energy market during the analysis period. External sources were used to provide context for interpreting the results, as discussed in Chapter 9.

C. Attrition

See Chapter 7, Section 7.3, Attrition and Appendix A-5.

D. Regression Statistics

Regression statistics are provided for the final models in Appendix A-1.

E. Specification

The specification of the model is described in detail in Section 6.4.

1) Cross-sectional variation is addressed through the use of customer-specific intercepts.
2) Weather and time variables are included in the model to account for variations in use that are not associated with the installation of measures through the program. The electric models incorporate monthly dummy variables and an annual dummy variable is used in the gas model.
3) Since all participants with sufficient billing history were included in the final models, self-selection was not considered to be an issue.
4) The available data was insufficient to model all possible factors that impact energy use.
5) Net impacts are assumed to be equal to gross impacts.

F. Measurement Error

Measurement error is a factor in this analysis, as discussed in Sections 5.5 and 6.4.

G. Autocorrelation

In the electric model, autocorrelation is partially mitigated by the use of monthly dummy variables. Standard errors are estimated by bootstrapping to ensure that precision is not overstated due to autocorrelation. These issues are discussed in Section 6.5.3.

H. Heterosckedasticity

We did not conduct diagnostics for heteroskedacity. This decision was based on our use of the customer-specific intercepts (which mitigate heteroskedacity), the experience of our team members (who have found that heteroskedacity is often not a problem in this type of model) and the scope of the data issues with this evaluation (which seem to be more likely to affect the results than heteroskedacity.)

I. **Collinearity**

Collinearity is an issue with this data set, particularly with measures installed as a group. Alternative models were investigated, bundling some measures together. These issues are discussed in Sections 6.5.2 and 6.6, and results of the alternative models are presented in Appendix A-2.

J. Outliers

See 4.A above.

L. Precision

Standard errors are based on the bootstrap method, as discussed in Sections 6.3.4 and 6.5.4.

M. Engineering Analyses

Engineering analyses were not conducted as part of this study.

N. Net-to-Gross Ratio

The net-to-gross ratio was assumed to be 1 for this program.

4. Data Interpretation and Application

A. Net Impacts

Net impacts are assumed to be equal to gross impacts, as it consistent with the M&E Protocols for this program

Appendix D

Public Workshop:

Minutes and Comments

PY2002 LIEE Impact Evaluation Report Presentation and Public Workshop

Minutes

October 25, 2004

In Attendance:

Kathryn Parlin, West Hill Energy and Computing, Inc., 802-685-4424, kathryn@westhillenergy.com

Al Bartsch, West Hill Energy & Computing,Inc., 802-685-4424, al@westhillenergy.com

Bob Burt, Insulation Contractors' Association, 916-568-1826, bburt@macnexus.com

Long Nguyen, PG&E, 415-973-3610, lcn2@PGE.com

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Via Phone:

Mark McNulty

John Jensen, Richard Heath and Associates

Richard Shaw

The public workshop was held on October 25, 2004 at the Pacific Energy Center in San Francisco, starting at 1:00 PM. Twelve participants were present and three others participated via telephone. This report provides a summary of the workshop.

Josie Webb of the California Energy Commission opened the meeting. Kathryn Parlin of West Hill Energy & Computing, Inc. presented the results of the 2002 LIEE Impact Evaluation. A copy of this presentation can be downloaded at www.liob.org.

After the presentation, the following questions were posed and answered. The first set of questions were faxed by John Jensen of Richard Heath and Associates, Inc.

FAXED question: Can you elaborate on your conclusions in section 9.3, in particularly the part where you state "The lack of savings for space heating related measures found in the electric model and generally low level of savings in the gas model should not be considered to reflect the actual program impacts during a 'normal' year. It is highly likely that enhanced program tracking and a return to more typical consumption patterns will show real and significant savings for at least some of these measures."

Response: The analysis period encompassed the 2001 California Energy Crisis, a period of high volatility in the energy markets. The consumption data provided by the utilities indicates that there was reduced consumption during the energy crisis and a subsequent rebound. Independent sources provide evidence to support this trend, suggesting that voluntary conservation occurred during this period. As Karen DeGannes pointed out in an earlier meeting, some savings occurred due to the energy crisis and the LIEE savings estimated in our analysis are over and above these savings. The energy crisis savings are not incorporated into the analysis. (Kathryn Parlin)

FAXED question: Please explain how the savings for water heater measures were developed? As an example explain how the estimated coefficients for the gas model became the showerhead savings in Table 7-17? Were spread factors used? How did you differentiate between PG&E, SoCalGas and SDG&E? Is the savings per showerhead or home?

Response: The DHW measures were treated as a package in the regression analysis. The total package savings estimated from the regression models were compared to the aggregate deemed savings from the DEER study reflecting the mix of measures in the sample, and a realization rate was calculated. This realization rate was then applied to the deemed savings for each measure from the DEER study. (Kathryn Parlin)

For the electric DHW savings, three models were developed, one for each utility. For the gas savings, a combined model was run for all the utilities. Differences by utility may reflect the difference in the DEER study for the various utilities. The savings are per showerhead or aerator for showerheads and aerators and by home for pipe insulation and DHW water wraps. (Kathryn Parlin)

FAXED question: The same question was posed for the package of space heating measures.

Response: The same process described for DHW measures was also used for the package of space heating measures.

FAXED question: In reviewing the number of water heating measures installed it appears that showerheads and faucet aerators seem to have the highest frequency. The tank wraps seem to account for 55% of the water heating savings. Please explain how this works?

Response: This question referred to the savings tables in Chapter 7 and appears to be the result of a misinterpretation of the tables. The claim that tank wraps account for 55% of the savings was apparently based on the assumption that one of each device (i.e., one showerhead, one aerator, a tank wrap and pipe insulation) was installed in each home. However, the total program savings for the DHW package takes into account the actual mix of measures installed. (Kathryn Parlin)

FAXED question: In reviewing the number of space heating measures installed it appears that insulation seems to have the lowest frequency and the largest savings. Please explain how you were able to estimate the insulation savings for SDG&E when only 7 multifamily homes had insulation added? What frequency is sufficient to yield accurate savings estimates by measure from the space heat conservation variable in the gas model?

Response: We did not separately estimate attic insulation savings for multifamily homes in San Diego. The regression model provided the attic insulation savings for all of the participants in the gas model. This number was then adjusted based on the differences in the space heating requirements of multifamily and single family homes. (Kathryn Parlin)

Question: How were the numbers adjusted for heating and cooling degree days? (Kevin McKinley)

Response: The impacts for each house were calculated using the normalized weather data and the results were then averaged for the service territories. (Kathryn Parlin)

Question: Why couldn’t the impact of 2001 energy crisis be quantified? (Bob Burt)

Reponse: The available data were insufficient to quantify the effects of the Energy Crisis. The model included only binary indicators and it is not possible to account for all aspects of the crisis as it occurred slowly throughout the time from of the study period. (Rick Ridge)

Also, the Energy Crisis did not have a consistent impact on all measures. The regression model provided solid savings for refrigeration and the lighting savings also appear to be in a reasonable range. However, problems occurred with space and water heating, and cooling measures. The difficulty with estimating these savings may be due to the discretionary aspect of these end uses in much of the service terrority. Another issue is that space and water heating fuels are frequently the same and homes receiving water heating measures most often also received space heating measures, creating a high degree of collinearity between these sets of measures. The model showed an increase in weather dependent usage in the post period that made it impossible to identify savings for electric space heating measures. This effect is possibly due to increased thermostat settings in the post period. The gas model also showed lower use during 2001, increasing in 2002 and 2003. (Kathryn Parlin)

QUESTION: Were the evaluators asked to assess non-energy benefits? The effects of the Energy Crisis found by the regression analysis would argue for higher benefits. (Bob Burt)

Response: Quantifying non-energy benefits was not a part of this project. (Kathryn Parlin)

Question: Does the analysis actually show that thermostat setting were raised in the post-installation period? (Karen DeGannes)

Response: Higher thermostat settings are one explanation for the regression results. However, we do not have sufficient information to state definitively that thermostat settings were increased during the post-installation period. (Kathryn Parlin)

Comment: Non-energy benefits should be reviewed in the near future. (Bob Burt) There was general agreement that the non-energy benefits may be understated.

Comment: Bob stated that he agreed with the recommendation for collecting additional data but expressed concern as to whether accurate demographic data could be collected.

Question: Was the increased use observed from some measures reflected in the total program savings? (Bob Burt)

Response: No. In the draft report, the measures with increased use were omitted from the total program savings. The SAT committee discussed this issue and decided to report the increase use separately from the program savings. This adjustment will be made in the final report. (Kathryn Parlin)

Comment: Bob also observed that showerhead savings were higher in multifamily than in the single family homes. Kathryn Parlin said the scale came from the DEER study but that she would check on it.

The public workshop was adjourned at 2:30 PM.

Comments on the PY2002 LIEE Impact Evaluation

Submitted by San Diego Gas & Electric Company (SDG&E) and Southern California Gas Company (SoCalGas)

November 1, 2004

San Diego Gas & Electric Company (SDG&E) and Southern California Gas Company (SoCalGas), (Joint Utilities), submit the following comments on the Draft Impact Evaluation of the 2002 California Low Income Energy Efficiency Program Report (the Draft Report) revised October 11, 2004. The Joint Utilities have been active participants in meetings and conference calls where the evaluation inputs and results have been discussed and reviewed. The Joint Utilities believe that it would be inappropriate to use the findings of this evaluation to determine program design and savings in future years, specifically for those savings where the measures are dependent on the weather conditions because as the report indicates the data is not stable and therefore not reliable. The final report issued on the program should clearly articulate in the Executive Summary as well as throughout the report, the issues/concerns raised by the evaluation team with the validity of the data and results of the impact evaluation. Moreover, strong consideration should be given to including discussion on the appropriateness of the use of the results for future program planning and assessment purposes.

The authors of the Draft Report indicate that billing analysis was complicated for program year (PY) 2002 by the voluntary conservation efforts of California consumers during and after the Energy Crisis. It was not possible to estimate electric savings for homes with space heating and some cooling measures. Gas savings were also lower for many heating-relating measures than found in previous years, possibly resulting from external factors such as the Energy Crisis. The authors conclude the "…program savings developed from these estimates may understate the actual impacts." There are also various other cites in the Draft Report which support the Joint Utilities recommendation regarding the use of the findings of the impact evaluation for future program years.

Submitted by Richard Heath and Associates, Inc. (RHA)

November 4, 2004

RHA's General Comments

RHA appreciates the opportunity to comment on the Impact Evaluation of the 2002 California Low Income Energy Efficiency Program. We urge the Commission to use the results of this study with great caution. We believe that the energy savings estimates should not be used for any other purpose than to illustrate the impact of an energy crisis on low income electric and natural gas consumer behavior in the very short-run time-frame that was analyzed in the report's study period. We believe that the results of the 2001 Impact Evaluation should be used to measure load impacts for current and future program years since it is the most recent approved study and it does not suffer from the anomalies described by the West Hill Team in their report.

RHA's Specific Comments

During the workshop, we asked specific questions relating to the manner in which individual gas water heating (e.g., shower head) and individual gas space heating (e.g., envelope repair) savings were derived at the individual utility level. We are not satisfied that the energy savings for showerheads and envelope repair are being computed in a manner that reflects the work performed in the individual utility service area. The consultants used a single statewide gas model while individual utility electric models were used. We believe that a utility specific gas model rather than one statewide model would be more appropriate if billing analysis were the only estimation medium available.

We agree with many of the recommendations that the West Hill Team suggests for future studies. Collecting site specific data during the pre-installation period would enable better post-installation analysis. For example, we believe that a more appropriate approach to estimating the savings for showerheads and aerators would be to conduct pre and post-installation flow tests combined with an engineering analysis. Since the old devices were long gone, the evaluation contractors were only able to estimate savings with a billing analysis, which the consultants state is not very useful to estimate the energy savings for small measures.

For future studies we encourage the Commission to select the EM&V contractor during the program year so that a sampling of pre-installation data may be collected and to allow for alternative estimation approaches to be employed.

Response to Comments
Written by West Hill Energy and Computing, Inc.

RHA's General Comments

This issue is addressed explicitly in the final report in Chapter 10, Section 10.6 and Table E-3 of the Executive Summary. In brief, the final recommendations specify that "the PY 2002 estimated gas savings for space heating measures and the package of water heating conservation measures, and the electric savings for heating and cooling measures, should not be used for common program planning and reporting purposes." However, relying on the PY2001 evaluation results is not an appropriate solution for two reasons. First, the analysis period for the PY2001 evaluation also covers part of the 2001 Energy Crisis and there may be an unknown effect of this volatile period embedded in the 2001 savings estimates. Second, all of the data issues described in the PY2002 report also affected the PY2001 evaluation and some of the decisions made in the PY2001 study may have introduced systematic error into the results. For example, the 2001 savings for furnace replacements were based only homes that showed a drop in use between the pre- and post-installation period rather than all participants who received a new furnace through the program. Other differences between the methodology used in the PY2001 and PY2002 reports are explained in Chapter 6, Section 6.9 and Table 6-11.

As stated in the above-referenced sections of the report, we recommend that deemed savings, such as those found in the 2001 DEER Update Report, should be used for program planning purposes for gas measures and electric space heating and cooling measures, until better estimates can be obtained.

RHA's Comments on the Gas Model

RHA is correct that the electric savings were based on individual utility models, whereas the gas savings are estimated from a single, combined-utility model. This approach was selected due to the specific characteristics of the service territories and measures installed. For homes heated with gas, space heating can be a major component of the total energy use, but the weather-dependent use associated with space heating is difficult to identify in mild climates. The combined utility model represents a wider variation in weather effects than can be found in the service territory of any single utility, thus improving the overall ability of the model to estimate savings. This issue is not a concern with the electric model, where electric space heating is rare and the variations in cooling climate are substantial within PG&E's and SCE's territories