Impact Evaluation of the 2005 California Low Income Energy Efficiency Program

Draft Report

Submitted to

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Executive Summary

E.1 Objectives and Approach

This report comprises an impact evaluation of the California Low Income Energy Efficiency Program (LIEE) for program year 2005 (PY2005). 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). The study team, led by West Hill Energy & Computing, includes the Energy Center of Wisconsin, Ridge and Associates, Wirtshafter Associates, and Katherine Randazzo, referred to collectively as the "West Hill Energy Team" or the "Team."

The Study Advisory Team (SAT) approved the research plan and provided feedback at each stage. Each of the four participating utilities and the California Public Utilities Commission (CPUC) were represented on the SAT and the West Hill Energy Team found their input to be invaluable at many stages of this study.

Previous impact evaluations were conducted for program years 1998, 2000, 2001 and 2002. In CPUC Decision 03-10-041, the CPUC specified that impact evaluations should take place every two years. However, the LIEE impact evaluation for PY2002 recommended improvements to the data collection for improving future impact evaluations, and given the lead time required to make these changes, the CPUC decided to postpone the impact evaluation originally scheduled for 2004 until PY2005.

The previous four LIEE evaluations were based on billing analyses, a decision that was largely dictated by the availability of data, time frame and budget. However, there were ongoing issues with lack of critical data at the program level and also concerns about the influence of external, non-program influences. The period of 2000 to 2003 encompassed the 2001 California Energy Crisis and was generally a period of volatility that affected energy prices and consumption. These conditions contributed to variations in program savings from year to year and concerns about the reliability and consistency of the savings.

E.2 Overview of Methods

The 2002 LIEE impact evaluation included a thorough review of possible impact evaluation strategies that could be applied to the LIEE.[1] A limiting factors for the LIEE program is that little detailed pre-installation data are collected as part of the energy assessment.[2] Applying alternative strategies, such as engineering methods or metering, to

[1] Impact Evaluation of the 2002 California Low Income Energy Efficiency Program, Final Report, West Hill Energy & Computing, Inc.,July, 2004, Chapters 1 and 5.

[2] For example, in states with colder climates than California, such as Vermont and New York, the initial audit often includes a blower door test that determines the infiltration rate and allows for the estimation of savings of air sealing measures by comparing pre- and post-installation tests. Incorporating a blower door test into every audit is not necessarily appropriate in California, considering its mild heating climate in many areas. However, air sealing measures are installed in most of the homes served by the gas utilities and comprise a noticeable percentage of the total program savings. Without pre- and post-installation blower door tests, there are no reliable engineering methods to assess the savings.

the LIEE program would require a completely different research design that would include some method of acquiring the pre-installation, technical data at a sample of homes, and would thus necessitate a long lead time, beginning substantially before the program year to be evaluated.

Given that the evaluators were brought on board in 2003 for the PY2002, the review of potential methods led to the conclusion that a billing analysis was the only option given the time frame and budget. The results of this evaluation indicated that the overall savings and some of the measure-specific savings were quite low in comparison to other research into residential savings. However, the downside of this approach was that only external studies regarding general energy use during the period were available to try to interpret the low savings estimates stemming from the billing analysis. In particular, savings from heating and cooling measures were difficult to estimate and the savings for CFL bulbs and DHW conservation devices were substantially lower than found in other research.

The 2005 evaluation was designed to use billing analysis as a primary tool for estimating savings, and also to tap information from numerous sources to inform and understand the results of the billing analysis. The primary purpose of this impact evaluation was to estimate the first year savings for the variety of measures installed through the program at the household and measure level. In addition, this study was designed to improve the savings estimates for certain key measures, including lighting, cooling and gas domestic hot water (DHW) low flow measures. Secondary objectives included investigating the effectiveness of the energy education component of the program on a qualitative basis and assessing opportunities for improving program cost-effectiveness.

The work plan involved six specific tasks designed to achieve these objectives:

1. Review of program delivery by the West Hill Energy Team
2. Improving the program-level data collection
3. Showerhead survey to assess flow rates of the original (pre-installation) showerheads
4. On-site survey of PY05 participants
5. Billing analysis to estimate household and measure-level savings
6. Review of external evaluations to compare savings and provide context where needed

Table 1 below shows the relationship between the specific tasks listed below and these objectives.

Table 1: Tasks and Objectives

Task	Improve Measure Estimates	Investigate Energy Education	Improve Cost Effectiveness	Estimate Household & Measure Savings
Review of Program Delivery	X	X		X
Improved Data Collection	X			X
Showerhead survey	X			X
On-site surveys	X	X	X	X
Billing Analysis				X
Review of External Evaluations	X		X	X

The tasks are divided into three phases. Phase I covered the review of the program delivery, improving the data collection and fielding the showerhead survey. Phase II consisted of the on-site survey and Phase III involved the billing analysis, reviewing external evaluations as needed and integrating the results into the draft and final reports.

E.3 Results

Overview

A combination of the billing analysis, showerhead/aerator survey results, the on site surveys and external sources were used to develop estimates of actual program savings. For each measure, the results of the regression analysis were compared to estimates from previous evaluations, external studies, and other data collected through the showerhead and on-site surveys in an effort to triangulate on estimates of energy impacts. The information-theoretic model selection process provided an objective basis for selecting among the candidate models and avoid results-based analysis. In aggregate, this process allowed us to place the results in context, identify potential biases in the estimators, and develop the most defensible estimate of savings for each measure.

Table E1 shows the annual estimated household savings for the 2000, 2001, 2002 and 2005 evaluations, along with the annual kWh consumption for the group of 2005 program participants used in the regression models, during the pre-installation period.

Electric savings increase steadily from 175 kWh per year in PY2000 to 421 kWh in PY2005. The current savings estimate represents a decrease of approximately 8% in electric consumption on average. The PY2005 electric savings are about 15% higher than the savings found in the PY2002 evaluation, with the largest increase in SCE's service territory.

The gas savings are more variable from one year to the next. The average household savings for the statewide program are 20 therms per year, or 5% of gas consumption on average. The PY2002 evaluation showed a dramatic drop in savings, most likely due to the effects of the 2001 California Energy Crisis. The PY2005 household savings are more in line with the results of the 2000 and 2001 LIEE impact evaluations.

Table E1: Comparison of Household Savings, PY2000 to PY2005

	Average Annual Energy Consumption[3]	PY2005 Evaluation	PY 2002 Evaluation	PY 2001 Evaluation	PY 2000 Evaluation
Electric Savings (kWh)					
Combined Utilities[4]	5,431	421	366	213	175
PG&E	5,778	438	399	236	240
SCE	5,306	421	286	203	153
SDG&E	4,240	348	370	215	89
Gas Savings (Therms)					
Combined Utilities	421	20	8	18	24
PG&E	459	20	9	18	28
SDG&E	397	14	4	13	13
SoCalGas	323	20	8	20	26

Total program savings by utility are summarized in Table E2 below.

Table E2: PY 2005 Total Program Savings

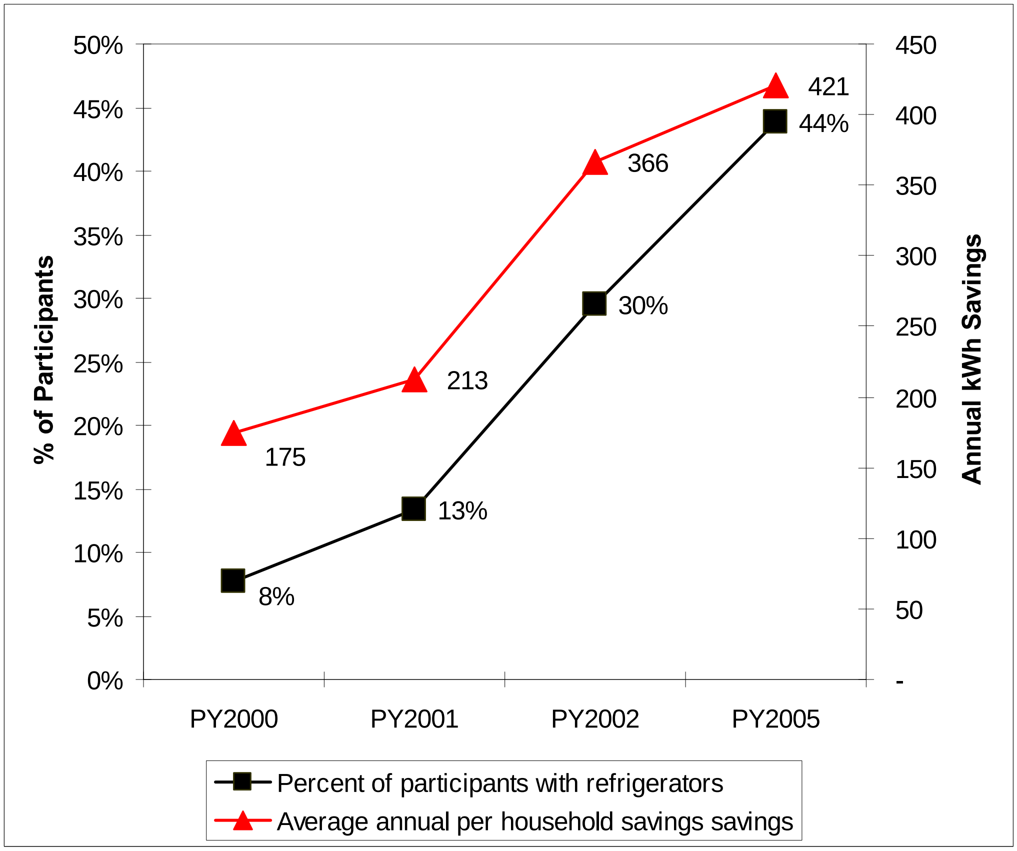
	# of Participants	Annual MWh	Annual Therms
PG&E	61,519	24,951	1,117,387
SCE	41,397	17,438	
SDG&E	13,737	4,717	156,387
SoCalGas	41,535		843,468
Totals	158,188	47,106	2,117,242

As was shown in the PY2002 impact evaluation, refrigerator installations are a major driver of the electric savings. The steady increase in household savings is matched by a higher penetration of energy efficient refrigerators. SCE had the highest penetration of efficient refrigerators in PY2005 with 48% of the LIEE household receiving one, following by PG&E with 42% penetration and SDG&E with 37%. Overall, about 44% of LIEE households received a new refrigerator. This trend of increasing savings and penetration of refrigerators is illustrated in Figure E1 below.

[3] This column reflects the average annualized kWh consumption for 2005 participants who were included in the account sample.

[4] Combined utility average consumption were calculated from the 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.

Figure E1: Household Electric Saving and Penetration Rates of Efficient Refrigerators



It is interesting to note that SoCalGas's per household savings of 20 therms is the equivalent of PG&E's, although the climate is milder in SoCalGas's territory. This result is largely due to the higher penetration of measures in SoCalGas's program. Almost all of the SoCalGas participants (96%) received both weatherization measures (air sealing and minor envelope repair) and DHW conservation devices, whereas about 70% of PG&E's gas participants received both of these sets of measures. SDG&E has the mildest heating climate and also a lower penetration of the combined package of weatherization and DHW conservation measures among its gas participants (about 68%).

One difference between the PY2002 and the PY2005 reports is that we have collapsed a number of the measures into single categories for the PY2005. In this manner, we are representing savings that can be more reliably estimated through the regression models, rather than parsing out savings to a degree that cannot be supported by the billing data. In particular, the all of the air sealing measures (such as caulking and weatherstripping) and minor envelope repairs are included as one variable and only the combined savings are estimated. As we have discussed with the SAT committee, these measures only achieve savings in aggregate, and savings for individual measures are meaningless.[5] The savings

[5] The 2005 DEER database does not provide separate savings for caulking and weatherstripping, but rather provides savings for a specific reduction in infiltration rate.

from the DHW conservation measures is also estimated as a package, rather than attempting to estimate savings separately for each component. This approach has no effect on the total program savings and provides more reasonable and defensible savings estimates.

Characteristics of the Population

A key to interpreting the potential savings from the LIEE program is understanding the energy characteristics of the population. Some of the relevant findings from the study are outlined below, with the source identified as from the billing analysis (BA), showerhead survey (SS), on-site survey(OS) or external studies (ES).

- Participants use less electricity than the average residential customer and have less opportunity for savings due to the lower penetration of electric space and water heating and cooling equipment (BA, ES).
- Participants in the gas program are more likely to have gas space and water heating than the residential sector as a whole, but still use less energy than the average residential customer (BA, ES).
- 24% of participants live in 1 person households and 24% live in households with more than 4 members.
- About a third of the survey respondents reported using their heating systems thirty days or less a year across the four climate zones represented in the sample (OS).
- Another 13% of participants have no heating system or a non-working system. The majority of these homes are located along the southern coast where the climate is quite mild. Most of these survey respondents did not receive heating system measures through LIEE (OS).

In aggregate, the range of evaluation tasks completed as a part of this study suggest that the LIEE population on average are low energy users, even prior to their participants in the program. This population, therefore, would be expected to have fairly low average savings.

Measure-Level Discussion

Information from the showerhead and on-site surveys and external sources were combined with the regression results to determine the most reliable estimate of savings. All of the gas savings were estimated from the regression model. Alternative methods were used for the electric measures that could not be reliably estimated from the regression model, as summarized in Table E3 on the following page.

Lighting

Lighting estimates are available from the regression analysis and were also estimated using engineering algorithms in conjunction with data collected during the on-site survey and other external sources of information. While the per bulb estimates for this program from the last three impact evaluations have generally been low, the current estimate from regression analysis is lower than the previous lowest estimate of 22 kWh per year by a wide margin at 11 kWh, with a 90% confidence interval of 6 to 16 kWh.

For comparison purposes, savings were also estimated using the hours of use and retention rates from the on-site survey, giving 21 kWh per year per lamp. The difference between this alternative estimate and the regression result is marked. Lighting savings are quite small in comparison to total use and can be difficult to estimate through a regression analysis. The relatively low retention rate suggests that the dummy variable indicating the installation of lighting measures is unreliable for a significant number of homes, which introduces error into the analysis and is likely to exert an downward bias on the estimator. In addition, the on-site survey indicates that many participants are purchasing CFLs outside of the program, which could be occurring throughout the analysis period and tends to make lighting use more variable.

These results would point to the possibility that the lighting savings from the regression model could be biased downward. However, the total household savings from the regression model should be reasonably robust, and since lighting comprises such a large part of the program savings, one would expect these savings to be found in the billing analysis. Given the major impact on the total program savings for even modest increases in the kWh per CFL savings estimate, we are reluctant to adjust this savings number by a large margin. We have adopted a compromise position of adjusting the savings per CFL upward from 11 kWh to 16 kWh per year, the upper bound of the 90% confidence level from the regression model.

Table E3: Summary of Savings for Electric Measures

Measure	Regression Result	Showerhead/ On-site Estimate	DEER/ External Studies	Previous LIEE Evaluations	Source of PY05 Savings Estimate
Lighting (per CFL)	11 kWh	22 kWh		22 - 43 kWh	Adjusted to be between regression and on-site estimate, at 90% upper confidence bound of regression result
Refrigerators	760 kWh	None	None	645 to 795	Electric regression model
Attic Insulation (heating)	252 kWh	None	180 kWh (2005)	35 - 288 kWh	Electric regression model
Attic Insulation (cooling)	23 kWh	None	None	44 - 208 kWh	Electric regression model
DHW Package	Not estimated	171 kWh (showerhead)	78 - 608 kWh (2001)	30 - 240 kWh	Convert savings from gas regression model
Cooling Measures	161 kWh	None	333 – 5056 kWh (2001)	98 - 571 kWh	Electric regression model
Air Sealing/ Envelope measures	Not estimated	None	None	10 - 56 kWh	Convert savings from gas regression model

DHW Conservation Package
The DHW package includes low flow showerheads and aerators, pipe insulation and tank wraps. Of these items, low flow showerheads and tank wraps are likely to have the greatest savings. While the showerheads are installed in most homes, tank wraps are rarely installed, suggesting that the primary source of the savings on average per home is likely to be associated with the low flow showerheads.

The gas savings for the DHW package are estimated to be 8.4 therms from the regression analysis. The electric model did not produce a reliable estimator for the package of DHW measures.

Flow rates and pressures levels from the showerhead and on-site surveys were used to estimate the savings from installed low flow showerheads, leading to the conclusion that these efficiency measures save 171 kWh or 7.3 therms per year.

The gas regression model and engineering methods produce results that are reasonably consistent with each other and the previous LIEE evaluations. The 8.4 annual therm savings from the gas regression model seem highly plausible, given that showerheads are assumed to produce the bulk of the savings and the alternative estimate suggests that these savings are 7.3 therms. Thus, the regression results are used to calculate the program savings for gas.

The electric regression model did not produce a reliable estimator for the DHW conservation package, which is largely due to the high coincidence of electric DHW and space heat, causing variability in the electric use and making it more difficult to assess savings. Unlike the gas model, where it was possible to provide a rough check on the DHW savings by looking at the months with low heating loads, the electric homes often do not have a lengthy seasonal period unaffected by heating or cooling loads.

It is reasonable to assume that these EDHW measures accrue savings and that these savings may not show up in the average household savings from the regression model due to the very low incidence of electric DHW. For this reason, we have estimated the savings for the electric DHW package by converting the gas savings to kWh and correcting for the different efficiencies of gas and electric water heating equipment, resulting in savings of 196 kWh per year.

Attic Insulation
Savings for attic insulation were estimated from both the electric and gas regression models, resulting in average savings of 252 kWh and 59 therms for heating and 22 kWh for cooling. The range of savings from previous LIEE evaluations is wide, from 35 to 288 kWh for electric heat, 10 to 59 therms for gas and 44 to 208 kWh for cooling. The 2005 DEER database indicates that savings from attic insulation are about 180 kWh and 41 therms.

The regression estimates for the electric and gas heating savings are within the range of the previous LIEE evaluations and 40% and 45% higher than the DEER savings for kWh and therms, respectively. However, the cooling savings are lower than found in the earlier LIEE evaluations. This difference could be partly due to the approach to the modeling.

The regression results for attic insulation seem to be in a reasonable range and were used to estimate the program savings.

Envelope and Air Sealing Measures
Savings for these smaller measures were part of the output from the gas model, but could not be reliably estimated from the electric model. The gas model indicates savings of approximately 9.5 therms per home, which is within the range of 2 to 11 therms found in the earlier LIEE evaluations. Our literature review did not turn up any other relevant evaluations to provide additional context for these numbers.

The savings from the electric model would lead one to conclude that electric use increased due to these measures, which is most likely due to the fact that most homes with electric space heat also have either electric DHW or air conditioning equipment or both, making the consumption in these homes much more variable.

The gas savings for these measures are estimated from the regression model. In the absence of better information, the electric savings are estimated from the gas results, adjusting for the difference in efficiency between the gas and electric heating systems and also for the difference in the use of electric space heat.

Refrigerators
Refrigerator savings were fairly stable and consistent in the previous evaluations, and were not identified as a targeted measure for this study. The on-site survey indicated that LIEE energy efficiency refrigerators have a high retention rate (95%).

The results of the billing analysis suggest that refrigerator savings are a bit more variable than anticipated. The weighted least square model produced savings of 760 kWh, but the savings from the unweighted model were about 16% lower at 642 kWh. The results from previous evaluations indicate that savings from efficient refrigerators range from 645 kWh per year to 795 kWh. Both of the current estimators fall close to or within this range, making it difficult to know whether one or both estimators are biased. While a recent study of a low income program with refrigerator replacement in Ohio found savings in the range of 800 kWh, it is not clear whether this information is applicable to the LIEE program given the differences in protocols among low income programs operating in other states.[6]

The weighted least squares model was the top-ranked model from the model selection process and is used for most of the other electric measures. Consequently, the estimate from the least squares model was also used for the refrigerator savings.

[6] *Op. cit.*, Blasnik, 2004.

Cooling Measures

The cooling measures include installing evaporative coolers and replacing room air-conditioners. Measure savings are estimated at 161 kWh from the regression model. The top-ranked model from the model selection process incorporated both of these measures into one variable, pointing to the conclusion that separating the two variables did not represent an improvement to the model.

A number of steps were taken to improve the modeling of cooling measures for the PY2005 evaluation. The first and most crucial action was for the utilities to collect information regarding the presence of working air conditioning equipment in the home and enter this data into the electronic tracking systems. The enhanced data collection allowed us to improve the modeling of cooling measures.

The on-site survey was also designed to gain a better understanding of the use of the new cooling equipment, although this information is qualitative in nature and did not permit alternative savings calculations. The retention rate for the cooling equipment is high and the survey found that many LIEE participants with cooling measures tend to use their air conditioning systems very little. It is not known whether this behavioral pattern was in place before the LIEE cooling equipment was installed.

It is also clear that some of the operating procedures for the evaporative coolers are not thoroughly understood by LIEE participants, with 35% reporting that they use the evaporative coolers with all windows closed at least occasionally and 16% that they sometimes use the refrigerant-based air conditioner and evaporative cooler at the same time.

In aggregate, these findings lead to the conclusion that the savings are likely to be quite variable from home to home and many homes may have low savings due to the restricted use of the cooling equipment. Failure to operate the evaporative cooler and refrigerant-base air conditioning correctly may also degrade savings in some homes.

Previous LIEE evaluations estimated savings for evaporative coolers at 45 to 618 kWh per year and A/C replacement savings at 80 to 571 kWh per year. Clearly, the current estimates are close to the bottom of this range. However, given the results of the on-site survey, the current estimate of 161 kWh seems to be within a reasonable range.

Heating and DHW System Repair and Replacement

The savings for heating system repair and replacement were estimated from the gas model, combined into one estimator. These savings were sufficiently small to make it unfeasible to try to parse them out into finer segments. The average savings for the heating system repair and replace from the regression model are 8 therms per year. The previous LIEE evaluations indicated savings ranged from 16 to 43 therms per year for furnace repair and 39 to 147 therms per year for furnace replacement. The lower estimates from the PY2005 evaluation are likely to be partially explained by differences in the approach to the modeling, and may better reflect the actual from the heating measures.

The DHW repair/replacement is estimated to save about 12 therms per year, based on the regression results. Measure savings were estimated to be 10 to 19 therms in the 2001 LIEE evaluation and 18 therms in the PY02 evaluation. This measure in infrequently installed, and does not make a large contribution to program savings. The PY05 estimate is on the low side, but still within a reasonable range.

The low savings from the regression model is consistent with the on-site survey results suggesting that many LIEE participants use their heating systems little or not at all. The heating system and DHW repair/replacement savings from the regression model were used to estimate program savings in the absence of compelling information to suggest that they are understated.

E.4 Recommendations

The recommendations discussed below are divided into five categories: reliability of savings, non-energy benefits, possible additional sources of savings for the LIEE program, data collection issues and suggestions related to program implementation.

Reliability of Savings and Considerations for Future Evaluations
The PY2005 evaluation was based on a billing analysis and informed by a number of other evaluation activities, including benchtesting of showerhead flow rates and an on-site survey of participants. The strategy allowed for internal and external validation of the measure and program savings. Even using this multi-faceted approach, the reliability of the savings varies at the measure level and housing type level, but the overall household savings are consistent with previous evaluations, the characteristics of the population and the features of the LIEE program as implemented. Estimating reliable savings at the measure and household level are challenging under any circumstances and the Team suggests that the SAT committee review its reasons for pursuing this approach.

The question remains whether the reliability of the savings could be improved. While it may be possible to improve the reliability, alternative strategies are likely to be significantly more expensive to implement, may not produce substantially different program-level savings and are not guaranteed to yield more reliable results. Consequently, pursuing other avenues, such as estimating non-energy benefits, may produce more useful results than incremental improvements to the reliability of the energy savings.

Non-Energy Benefits
It may be more fruitful to spend evaluation dollars investigating the potential non-energy benefits accruing from the program, such as comfort, water savings, moving funds from paying utility bills to other critical goods and services, and arrearage reductions. Recent research in this area has introduced some innovative approaches that may be worth pursuing, such as conjoint analysis.

It is entirely possible that the non-energy benefits associated with this program are substantial and could be underestimated in the current cost-effectiveness model. Also, program implementation may be further oriented toward achieving non-energy benefits, such as water savings. Pursuing these savings is likely to be more productive than continuing to try to make incremental improvements to the estimates of energy savings.

Additional Sources of Savings
A couple of opportunities for attributing additional savings to the program have come to our attention: water pumping, the retrofit of older washing machines, and cooling savings from attic insulation for SCE.

There are substantial potential savings from reducing water pumping use through low flow showerheads or other water-savings devices, as discussed in Chapter 8, Section 8.8. While these savings reflect a direct reduction in electricity use, they are not clearly associated with a specific utility. Our initial review suggests that up to 1.7 GWh could be added to the program savings, which would increase the total program savings by 4%. The issue becomes how to assign these savings to each utility.

The replacement of older, standard washing machines with horizontal axis models will substantially reduce total water use as well as water heating consumption for those participants who wash with warm or hot water. The combined water and energy savings could make such a retrofit cost effective. Many sources are available to estimate the savings from this measure, including the DEER database and Efficiency Vermont's reference manual. In addition, there are the potential savings associated with reducing water pumping use.

We think the analysis is underestimating the savings that is occurring when gas heated homes in the joint SCE/SoCal Gas area receive attic insulation. Because SoCal Gas does these jobs, there is not always a clear designation that the home has air conditioning and is served by SCE. The electric model showed small but significant cooling savings associated with homes that received attic insulation. However, these savings could only be identified in SCE homes with electric space heating and attic insulation, although SoCalGas may well have installed attic insulation in a number of the SCE homes. This situation could be alleviated by setting up a system to match joint SCE/SoCalGas participants in the program-level data sets.

Data Collection Issues
The utilities made substantial improvements during PY2005 in collecting the program-level data needed for evaluation. The most critical data fields are now being populated and are available for evaluation purposes. A few incremental improvements could still be made, as discussed below:

- Error-checking for some of the data fields could be improved, in particular SCE's house type field and SoCalGas's space and water fuel types and measure descriptions for heating system repairs and replacements.
- SoCalGas could establish a system to assign a single unique household identifier regardless of the combination of measures installed at the site.
- The utilities should track, either at the program- or measure-level, whether an evaporative cooler is a new installation or a replacement.

- SCE and SoCalGas should consider whether there is a mechanism to facilitate the matching of joint SCE/SoCalGas customers to allow the estimation of cooling savings for all homes that receive attic insulation.
- The utilities should investigate how to obtain information about LIHEAP installations in LIEE homes. This should be possible especially when the same contractor performs both LIEE and LIHEAP services.

These data enhancements would improve the next impact evaluation and should allow the estimation of additional and legitimate program savings.

Program Implementation Issues

Although this study was primarily an impact evaluation, a few issues arose that may be useful for improving program implementation. Some of the findings that may be relevant for program implementation are listed below.

- The energy education component of the study found some conservation actions with high potential savings, such as pulling down shades to reduce cooling use, had a low overall incidence and high attribution rate to LIEE, suggesting that focusing on recommendations with higher savings and lower acceptance may improve the impacts of this program component.
- About 35% of the LIEE-installed CFLs failed, had been removed or were never installed. This low persistence rate of the CFLs is a matter of concern, as well as 8% of program participants who responded that the CFLs were not actually installed. Improving the quality of the CFL lamps and ensuring their installation are small steps that could help boost program savings.
- The retention rate for showerheads and aerators was 80%, leaving substantial room for improvement.
- About 35% of the homes with LIEE evaporative coolers report that they do not always have a window open when the unit is operating, suggesting that education about the proper use of the cooling equipment is another worthwhile area to explore.
- Approximately 10% of LIEE household own a secondary refrigerator or freezer. Consequently, it may be worthwhile to incorporate information about the savings related to the retirement of secondary refrigerators into the energy education component and consider referring these participants to other utility or municipal efforts to collect secondary refrigeration equipment.
- The listed flow rate on the outside of the showerhead (when available) is not necessarily a good indicator of the fitting's flow rate, suggesting that identifying showerheads with a flow rate above 3.0 gpm is not a simple task.
- Some fittings are restricted by mineral deposits and others with signs of mineral deposits have been modified to allow for increased flow.
- The flow rates for the replacement, low flow showerheads are more variable than would be expected.

While not a primary objective of this study, these findings may provide useful feedback to program implementers.

E.5 Next Steps

There are a few outstanding issues and tasks that need to be completed before the report is finalized, as listed below.

- Estimate coincident peak demand savings for the program. The parties agreed that this would take place after the energy savings presented in the draft report were finalized.
- Estimate energy savings for weather-dependent measures by CEC Title 24 weather zone. It makes sense to hold off on this task until the energy savings have been finalized and the final tables can be constructed.
- Review the methods for breaking out savings by housing type.

E.6 Final Comments

The impact evaluations for this program from 1998 through 2002 were primarily based on a regression analysis of billing records. The utilities and the CPUC requested highly detailed results, with savings estimated by utility, house type, specific measures (over twenty) and climate zone. These studies produce savings estimates that tended to vary from year to year, particularly at the measure level.

In the 2002 LIEE impact evaluation, the overall savings and some of the measure-specific savings were quite low in comparison to other research into residential savings, which was likely due to the fact that the analysis period encompassed the California 2001 Energy Crisis.

While one would like to see more stable estimates of savings, we also need to recognize the limitations of the method. The fixed effects billing analyses employed for the last four evaluations, and also used in the current study, has strengths and weaknesses. Its strength is that it allows for the estimation of savings from a large group of the participants and does not require additional surveys that tend to be quite expensive. The weakness is that there is little or no house-specific information regarding changes in the household over time that may affect energy use.

In addition, residential billing is highly variable with most of the underlying reasons for the change in energy use having little to do with energy efficiency programs. Consequently, year-to-year variation in the results of the billing analysis should be expected and 15% accuracy in total program savings may be a reasonable outcome.

The 2005 impact evaluation was designed to try to improve the accuracy of the estimators by collecting data from other sources to gain a better understanding of the conditions in the household that affect energy savings and also to provide the basis for alternative calculations of savings for a couple of common measures, i.e., lighting and low flow showerheads. The objective was to provide context for interpreting the results and build the foundation for adjusting regression results that appear to be biased.[7]

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[7] As a point of clarification, the 2005 study was not designed to collect substantial information regarding changes in consumption at the household level to try to improve the fixed effects models. This strategy was tried by Xenergy for the PY2000 evaluation by fielding a telephone survey of 1,000 participants. However, it

The objective of this study was to improve the reliability of the LIEE program savings estimates by triangulation and improved modeling methods. This strategy produced some fascinating synergies and allowed us to place our results in a larger context. While the modeling results exhibited variability as is often the case in residential billing analysis, the testing of the showerhead flow rates, on-site surveys and review of other residential studies allowed us to conduct both internal and external validation of the savings. This process has produced solid and defensible program savings.

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did not yield plausible results and the final program estimates were based on the fixed effects model for all participants with sufficient billing history.

This reference to Xenergy's experience is not intended to suggest that collecting supplemental data to specify one’s regression models more fully is an ineffective strategy, but rather to emphasize that it is difficult to implement successfully and would require a large sample size involving in depth participant interviews that would go far beyond the level of data collected in the 2005 study. Even with the best research design, measurement error may still be substantial due to the timing of the survey and participant recollection.

1 Introduction

This report comprises an impact evaluation of the California Low Income Energy Efficiency Program (LIEE) for program year 2005 (PY2005). 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). The study team, led by West Hill Energy & Computing, includes the Energy Center of Wisconsin, Ridge and Associates, Wirtshafter Associates, and Katherine Randazzo, referred to collectively as the "West Hill Energy Team" or the "Team."

The Study Advisory Team (SAT) approved the research plan and provided feedback at each stage. Each of the four participating utilities and the California Public Utilities Commission (CPUC) were represented on the SAT and the West Hill Energy Team found their input to be invaluable at many stages of this study.

Previous impact evaluations were conducted for program years 1998, 2000, 2001 and 2002. In CPUC Decision 03-10-041, the CPUC specified that impact evaluations should take place every two years. However, the LIEE impact evaluation for PY2002 recommended improvements to the data collection for improving future impact evaluations, and given the lead time required to make these changes, the CPUC decided to postpone the impact evaluation originally scheduled for 2004 until PY2005.

The previous four LIEE evaluations were based on billing analyses, a decision that was largely dictated by the availability of data, time frame and budget. However, there were ongoing issues with lack of critical data at the program level and also concerns about the influence of external, non-program influences. The period of 2000 to 2003 encompassed the 2001 California Energy Crisis and was generally a period of volatility that affected energy prices and consumption. These conditions contributed to variations in program savings from year to year and concerns about the reliability and consistency of the savings.

1.1 Approach to the 2005 Impact Evaluation

The 2002 LIEE impact evaluation included a thorough review of possible impact evaluation strategies that could be applied to the LIEE.[8] A limiting factors for the LIEE program is that little detailed pre-installation data are collected as part of the energy assessment.[9] Applying alternative strategies, such as engineering methods or metering, to

[8] Impact Evaluation of the 2002 California Low Income Energy Efficiency Program, Final Report, West Hill Energy & Computing, Inc.,July, 2004, Chapters 1 and 5.

[9] For example, in states with colder climates than California, such as Vermont and New York, the initial audit often includes a blower door test that determines the infiltration rate and allows for the estimation of savings of air sealing measures by comparing pre- and post-installation tests. Incorporating a blower door test into every audit is not necessarily appropriate in California, considering its mild heating climate in many areas. However, air sealing measures are installed in most of the homes served by the gas utilities and comprise a noticeable percentage of the total program savings. Without pre- and post-installation blower door tests, there are no reliable engineering methods to assess the savings.

the LIEE program would require a completely different research design that would include some method of acquiring the pre-installation, technical data at a sample of homes, and would thus necessitate a long lead time, beginning substantially before the program year to be evaluated.

Given that the evaluators were brought on board in 2003 for the PY2002, the review of potential methods led to the conclusion that a billing analysis was the only option given the time frame and budget. The results of this evaluation indicated that the overall savings and some of the measure-specific savings were quite low in comparison to other research into residential savings. However, the downside of this approach was that only external studies regarding general energy use during the period were available to try to interpret the low savings estimates stemming from the billing analysis. In particular, savings from heating and cooling measures were difficult to estimate and the savings for CFL bulbs and DHW conservation devices were substantially lower than found in other research.

The 2005 evaluation was designed to use billing analysis as a primary tool for estimating savings, and also to tap information from numerous sources to inform and understand the results of the billing analysis. The primary purpose of this impact evaluation was to estimate the first year savings for the variety of measures installed through the program at the household and measure level. In addition, this study was designed to improve the savings estimates for certain key measures, including lighting, cooling and gas domestic hot water (DHW) low flow measures. Secondary objectives included investigating the effectiveness of the energy education component of the program on a qualitative basis and assessing opportunities for improving program cost-effectiveness.

The work plan involved six specific tasks designed to achieve these objectives:

7. Review of program delivery by the West Hill Energy Team
8. Improving the program-level data collection
9. Showerhead survey to assess flow rates of the original (pre-installation) showerheads
10. On-site survey of PY05 participants
11. Billing analysis to estimate household and measure-level savings
12. Review of external evaluations to compare savings and provide context where needed

Table 1 below shows the relationship between the specific tasks listed below and these objectives.

Table 1: Tasks and Objectives

Task	Improve Measure Estimates	Investigate Energy Education	Improve Cost Effectiveness	Estimate Household & Measure Savings
Review of Program Delivery	X	X		X
Improved Data Collection	X			X
Showerhead survey	X			X
On-site surveys	X	X	X	X
Billing Analysis				X
Review of External Evaluations	X		X	X

The tasks are divided into three phases. Phase I covered the review of the program delivery, improving the data collection and fielding the showerhead survey. Phase II consisted of the on-site survey and Phase III involved the billing analysis, reviewing external evaluations as needed and integrating the results into the draft and final reports. The activities associated with each phase are described in more detail below.

1.1.1 Phase I

The Team concluded that having a better understanding of the program delivery was critical to interpreting the program data to be used in the billing analysis as well as the results of the analysis. To this end, the West Hill Energy team initially conducted phone interviews with program staff, followed by ride alongs on LIEE energy assessments and measure installations in each utility territory. The purpose of these site visits was to provide us with a better understanding of the actual issues that arise in the field and how they may affect the program savings. The memo outlining the findings from ride alongs is attached as Appendix A.

Another component of Phase I involved improving the program-level data collection. The 2002 LIEE Impact Evaluation Report[10] identified a number of data issues that if resolved could improve the accuracy of future impact evaluations. In late 2004 and early 2005, the West Hill Energy team worked with the utilities to add specific data fields to the forms used by the field staff and these changes were implemented during the first quarter of 2005. The memo describing the process and results is included as Appendix B.

The third component of Phase I was a survey of showerheads to determine the flow rates of the showerheads removed from the participants' homes. Selected program contractors were asked to collect the old showerheads and send them to a testing facility for bench testing of the flow rates at four pressures. The results of this analysis were subsequently combined with information from the on-site survey to estimate the savings from low flow showerheads. The findings from the showerhead survey are incorporated into this report as Appendix C.

[10] *Op. cit.*, West Hill Energy & Computing, Inc., 2004.

Another question that arose from the previous four evaluations was whether it was possible to improve the estimates of savings by housing type. In particular, mobile homes were eliminated from the billing analysis as a extremely high rate due to the prevalence of master-metering in mobile home parks. As part of Phase I, the Team researched the possibility of obtained submetered data for mobile homes, and also considered incorporating alternative approaches of estimating savings by house type into the billing analysis. The memo detailing the investigation into obtaining submetered billing data for mobile homes is attached as Appendix E, and this issue is explored further in Chapter 4, Section 4.4.

1.1.2 Phase II

The primary Phase II activity consisted of the on-site survey. The on-site survey was designed to support the quantitative components of the impact evaluation through primary research into issues that directly affect energy usage and the expected savings from LIEE-installed measures. It also entailed a qualitative analysis of the energy education component and possibilities for improving program cost-effectiveness.

A two-stage cluster sample of 400 LIEE participants was selected and ASW Engineering of Tustin, California conducted the field work. Eighty of the 400 surveys were targeted toward LIEE participants with cooling measures and included additional detail related to air conditioning (A/C) and evaporative cooler use.

This survey provided a wealth of information regarding the saturation, use and condition of the primary energy-using equipment. Review of external evaluations was a critical component in developing alternative estimates of savings from the data collected through the showerhead and on-site surveys.

1.1.3 Phase III

The billing analysis formed the basis for many of the measure-level savings presented in the results section. This process involved combining the program- and measure-level data with billing and weather data to create a pooled, cross-sectional, time-series regression model.

This component of the study also involved interpreting the results from all of the surveys and analyses conducted to date into the draft report. Information of all aspects of the study was integrated to produce the final estimates of program savings.

This multi-faceted approach allowed for alternative strategies when the billing analysis results were inconclusive or appeared to be unreliable. The savings for each measure were evaluated in the context of the improved program-level data, the information on the condition and use of energy-related equipment from the on-site and showerhead surveys, and the range of savings from impact evaluations of the LIEE program from previous years and of other relevant programs.

1.2 Next Steps

There are a few outstanding issues and tasks that need to be completed before the report is finalized, as listed below.

- Estimate coincident peak demand savings for the program. The parties agreed that this would take place after the energy savings presented in the draft report were finalized.
- Estimate energy savings for weather-dependent measures by CEC Title 24 weather zone. It makes sense to hold off on this task until the energy savings have been finalized and the final tables can be constructed.
- Review the methods for breaking out savings by housing type.

The final report is scheduled to be completed at the end of October, 2007.

1.3 Organization of the Report

The remainder of this report is divided into eight chapters. A description of the program is provided in Chapter 2. The third chapter covers data collection issues and discusses the changes made for the utilities and the implications for this analysis.

The fourth chapter provides some background on the program participants, including a summary of program activity and measures installed, a review of the pre-installation energy consumption patterns and an analysis of mobility among the population. The next chapter outlines the results of our qualitative review of the LIEE energy education and some issues affecting program implementation.

The theory behind the model selection and regression analysis is explained in Chapter 6, and the following chapter covers the application of the theory to the analyses presented in this report. Chapter 8 contains the results, followed by conclusions and recommendations in the final chapter.

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 *Low Income Energy Efficiency Program Statewide Policy and Procedures Manual, December 2003* (P&P Manual).

The P&P Manual specifically calls for the installation of compact fluorescent lamps (CFL) in each home.

> *"The electric or dual-fuel utility outreach worker will install compact fluorescent light bulbs during the initial home visit. The number of compact fluorescent light bulbs installed will depend on unit type, feasibility and*

> *amount of time each lighting fixture is used (3.5 hours minimum); however, no more than five (5) bulbs may be installed in a home. Leaving compact fluorescent light bulbs with customers for installation at a later time is not allowed."[P&P Manual, p. 4-3.]*

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. Eligible measures are listed in Table 2-1 below.

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 individual energy efficiency measures offered through the LIEE Program or other Programs offered to low-income customers by the utility,
- Practices that diminish the savings from individual energy efficiency measures, as well as the potential cost of such practices,
- Ways of decreasing usage through changes in practices,
- Information on CARE, the Medical Baseline Program, and other available programs,
- Appliance safety information,
- The way to read a utility bill, and
- The procedures used to conduct natural gas appliance testing (if applicable).

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.

Table 2-1: Eligible Measures for PY 2005[11]

Measure	SCE Program Non-Overlap Area	SoCal Program Non-Overlap Area	SCE / SoCal Gas Overlap Area Program (1)	SDG&E	PG&E
Attic Insulation	Yes	Yes	***Yes*** (3)	Yes	Yes
Low Flow Showerheads	Yes	Yes	***Yes*** (3)	Yes	Yes
Water Heater Blankets	Yes	Yes	***Yes*** (3)	Yes	Yes
Door Weather-stripping	Yes	Yes	***Yes*** (3)	Yes	Yes
Caulking	Yes	Yes	***Yes*** (3)	Yes	Yes
Outlet Gaskets	Yes	Yes	***Yes*** (3)	Yes	Yes
Faucet Aerators	Yes	Yes	***Yes*** (3)	Yes	Yes
Pipe Wrap	Yes	Yes	***Yes*** (3)	Yes	Yes
Evaporative Coolers	Yes	No	***Yes*** (2)	Yes	Yes
Furnace Repair/Replacement (4)	***No***	Yes	***Yes*** (3)	Yes	Yes
Refrigerator Replacement	Yes	No	***Yes*** (2)	Yes	Yes
Evaporative Cooler Covers	***Yes***	Yes	***Yes*** (3)	Yes	Yes
Hard-Wired Compact Fluorescent Porch Light Fixtures	Yes	No	***Yes*** (2)	Yes	Yes
Thread-In Compact Fluorescent	Yes	No	***Yes*** (2)	Yes	Yes
High efficiency window/wall air conditioners	Yes	No	Yes (2)	Yes	Yes
Minor Home Repairs (5)	Yes	Yes	Yes	Yes	Yes

Notes to Table 2.1:
(1) In the SoCalGas/SCE overlap area, measures are provided under a joint utility agreement. No interutility agreements are currently in place for other overlap areas; however, such agreements will be negotiated as soon as practicable.
(2) Not offered by SoCalGas under the joint utility agreement, but offered by SCE outside the jointly administered SoCalGas/SCE program.
(3) In the SCE/SoCalGas overlap area, SoCal Gas installs all feasible measures other than electric equipment measures (evaporative coolers, refrigerator replacements, compact fluorescents, hard-wired compact fluorescent porch light fixtures, and high efficiency window/wall air conditioners). See note (2). Approval is solicited by program service providers from SCE prior to the installation of other electric measures (e.g., ceiling insulation in electrically-heated homes) under the terms of a Joint Interutility Agreement.
(4) Furnace filter replacements are offered only as part of furnace repair. Moreover, programmable thermostats are offered only when required by local code in conjunction with furnace replacement.
(5) There are multiple submeasures included under minor home repairs. For the purposes of qualifying a home for the Program, all minor home repairs (combined) count as a single measure.

[11] *2003 Statewide P&P Manual*, p. 5-2.

3 Data Collection And Issues

The data collection issues associated with this project range from the billing and program-level data provided by the utilities to the direct collection of information by the Team through the showerhead and on-site surveys. The data collection, sampling and other methodological issues for the Team's surveys are discussed in Appendices B and C.

This chapter covers the information that was obtained from the utility program and customer information systems. The first section provides a summary of the changes in program data collection implemented for PY2005 and the second reviews the data transfer process and ongoing issues with the PY2005 utility data provided for this study.

3.1 Program-level Data Improvements

The 2002 LIEE Impact Evaluation Report[12] identified a number of data issues that if resolved could improve the accuracy of future impact evaluations. The issues fell into three broad categories: (1) the scope of the data being collected, (2) data collection procedures and (3) inconsistencies in specific fields. For example, whether or not a heating system was operational prior to being replaced through the LIEE program was not part of the program tracking data. This made it impossible to know if the installation would result in a decrease or an increase in use. The complete discussion of these issues can be found in Section 4.2 of the PY2002 LIEE Impact Evaluation Report.

In late 2004/early 2005, the Team worked with the utilities to address the data issues identified in the PY2002 LIEE Impact Evaluation. 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

Our team identified a list of specific fields to be added to the program collection forms and negotiated with the utilities to implement the changes. For the most part, the supplemental data collection process was in place by the end of the first quarter of 2005. This process was evaluated in the fall of 2005 and the results were documented in a memo included as Appendix B. Overall, there was a significant improvement in the data needed to assess the impacts of some measures.

[12] Impact Evaluation of the 2002 California Low Income Energy Efficiency Program, Final Report, West Hill Energy & Computing, Inc., July, 2004.

Some of the critical new fields and their effect on the billing analysis are discussed below, followed by a discussion of the additional program-level data requested by the Team and ongoing data issues that could still be improved.

3.1.1 Space and Water Heating Fuels Types

The fuel types for space and water heating are key inputs for defining the models and determining where savings should be found. For example, it would not be productive to look for electric savings from low flow showerheads if the home had a gas-fired water heater.

During the process of conducting the PY2002 evaluation, we discovered that the utilities' designators of the fuel type for space and water heating were generally not collected at the time of the energy assessment and might not be completely reliable. In the absence of other acceptable options, our team decided the best approach was to use the utility designators in the models regardless of the reliability.

In the three impact evaluations conducted prior to PY2002, the analysts used a combination of methods that included assigning fuel types to households based on consumption patterns when the utility designators were missing or appeared to be unreliable. While homes with air conditioning (for example) are likely to exhibit a wide range from consumption patterns during the cooling months, from no cooling load to substantial use, identifying homes as having air conditioning equipment based on consumption patterns will only pick up those homes with clearly measurable cooling loads. Thus, the savings for cooling measures will not reflect the range of cooling habits and may be overstated.

In PY2005, the utilities began recording the fuel type for space and water heating at the time of the energy assessment. This approach allowed us to identify those homes with these major end uses without resorting to *ad hoc* methods. While it is likely to improve the reliability of the savings, we must also acknowledge that correctly identifying all homes with air conditioning regardless of the use of the equipment by occupants will add variability to the model estimates.

The utilities also provided information regarding the presence of heat pumps and secondary heating systems of a different fuel type. It turned out that few participants have a heat pump or secondary heating source, suggesting that the modeling results are unlikely to be affected by these factors.

3.1.2 Working Heating and Cooling Systems

For the PY2002 study, there was no sure method to assess whether the heating system or cooling system was operating prior to the repair or replacement. This issue had two implications: first, it was not possible to determine whether a heating system repair and replacement would result in an increase or decrease in use and second, if the heating system was not working during the pre-installation period, one would not expect to find savings for other space-heating related measures such as attic insulation or air sealing measures.

As part of the data collection enhancements in PY2005, the utilities began tracking whether the heating system and cooling systems were working at the time of the energy assessment. This supplemental information provided the opportunity to improve the models used for the billing analysis. In addition to the two issues described above, it was also possible to directly model the increase in use in homes with non-functional space heating equipment which was repaired or replaced by LIEE.

3.1.3 Program- and Measure-Level Information

As part of the PY2005 data transfer from the utilities to Team, the parties expanded the list of data fields to include demographic information on the LIEE households and also some measure-level details. The demographic information included income, number of occupants and disability status, and was helpful for constructing the profile of participants presented in Chapter 4.

The expanded data fields also included the date of the energy assessment, the contractors providing the energy assessment and installation services, installation details for homes receiving attic insulation and the wattage of the CFL's installed. The date of the energy assessment was used to identify the end of the pre-installation period for the billing analyses, ensuring that any reduction in use resulting from the energy education will be likely to be captured in the measure estimators.

The utilities also provided the existing and installed R-value for homes that received attic insulation. This information was used to develop scaled estimators for use in the regression analysis, although these models did not rise to the top of the candidate models included in the model selection process. In addition, this supplemental data made it possible to match up the DEER savings estimates for attic insulation to the LIEE participants, for comparison purposes.

The installation contractor was also a valuable piece of information. During the ride-alongs, our team realized that some contractors are also working for the federal Low Income Home Energy Assistance Program (LIHEAP) and measures could be installed in a particular home either through LIHEAP or LIEE or a combination. Thus, some measures not identified in the LIEE measure list could be installed in the PY2005 participating homes, and we would not be aware of it. Comparing the list of LIEE contractors to the LIHEAP list, we were able to identify those who are provided services through both programs. This supplemental information allowed us to model the "LIHEAP effect" in the regression analysis.

We had initially anticipated that the wattage of the CFL's could be used to estimate the original wattages of the removed incandescent bulbs. However, after the ride-alongs we realized that the field staff often has only one type of CFL and they are used in a variety of situations, indicating that the correlation between the wattage of the CFL and the wattage of the original bulb is likely to be quite weak.

3.1.4 Ongoing Data Issues

The data collection improved substantially from PY2002 and the Team appreciates the time and effort devoted by the utilities to expanding the data collection in the field. In general, timely delivery and a more thorough review of the data files prepared in response to Team's data requests would greatly facilitate the data transfer process. There are just a few remaining issues that may improve the next evaluation without placing any undue burden on program or administrative staff, as explained below.

SCE still had a substantial number of participants with no house type (about 1,100), which seems like a simple error-checking issue.

About 20% of SoCalGas's participants were marked as having "other" fuel types for space and/or water heating, which also appears to be a lack of error-checking. In comparison to the PY2002 evaluation, where about 95% of the participants used natural gas for both space and water heating, concluding that 20% of SoCalGas customers use a different fuel type seems highly suspect.

The Team further suggests that SoCalGas consider establishing a unique household identifier to facilitate the enumeration of participants. In PY2005, homes that received both weatherization and heating system replace/repair measures were assigned two different household identifiers and could easily be counted as two participants. This approach created confusion, since eliminating one record at the program level would make the program counts correct but would then complicate our ability to match program- and measure-level information.

During PY2005, the LIEE Program installed new evaporative coolers in homes with refrigerant-based A/C systems and also replaced existing evaporative coolers that were in poor condition. However, it was not possible to determine from the measure-level data whether the evaporative cooler was replaced or was a new installation, and the type of installation could have an effect on measure-level savings. This piece of information should be incorporated in to program implementation and provided at either the measure-level or the program-level.

It may also be worthwhile considering whether there is a method to match up the SCE and SoCalGas customers who participate in the joint LIEE program. Issues with identifying homes as overlapping SoCalGas/SCE participants substantially complicated drawing the sample frame for the on-site survey.

There are also other considerations. With this supplemental information, it may be possible to attribute additional savings to the SCE program. For example, the electric model showed some cooling savings for homes with attic insulation. However, it was not possible to identify SCE homes who received attic insulation from SoCalGas, although any home with cooling equipment would be expected to achieve savings regardless of the space heating fuel. Being able to identify SCE/SoCalGas overlap homes with cooling equipment, and attic insulation installed by SoCalGas would have two positive impacts:

- it would allow the estimation of cooling savings for a much larger group of SCE participants and
- it may also improve the modeling results since it would now include all homes with attic insulation rather than just a subset of those homes.

Clearly, a coordinated effort between SCE and SoCalGas would be needed to implement this change in program procedures.

Finally, the Team suggests that the utilities develop a system for collecting information on LIHEAP installations in homes that are also treated by LIEE. SCE was able to provide that information for refrigerator installations. Since the contractors who provide services to both programs are regularly reporting to LIEE, it seems possible that they could also be asked to report on LIHEAP installations.

Currently, no information regarding the LIHEAP measures is available (except for SCE) and some LIHEAP savings could be included in the measure estimates. The modeling attempted to account for this effect by adding a "LIHEAP" variable associated with the overlapping contractors. However, additional measure-level information would allow the LIHEAP effect to be incorporated at the household level, which is likely to produce more reliable savings estimates.

3.2 PY2005 Data Collection

The data collection process for this study was lengthy, beginning in March of 2005 and continuing into June of 2007. The Team requested a variety of program, billing 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 of 2007, missing data continued to be identified as late as the middle of June, making it difficult to keep to the schedule. Fortunately, we were not working under a strict regulatory deadline.

The data sets themselves were extracted from the primary databases by the individual utilities and posted to a secure Web site set up for this purpose or 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.

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

- premise level consumption data from January 2004 through the most recent month available from each utility's customer information system for all of the premises that housed PY2005 participants
- daily weather data by weather station from January 1993 through the most recent available
- demographic data for PY 2005 participants from both the program tracking databases and the utilities' customer information systems

- Measure level data for PY2005 participants that was installed in PY2004 or PY2006
- premise level consumption data from January 2004 through most recently available from each utility's customer information system for all of the premises that housed PY2006 participants for use in a comparison group
- equivalent demographic data for PY 2006 participants from both the program tracking databases and the utilities' customer information systems for use in a comparison group
- aggregated CARE customer usage data from January 2004 to the most recent available to evaluate any trends general consumption.

In general, the utilities were responsive to our multiple and sometimes complex data requests, although specific issues arose on occasion and the time frame was expanded substantially. As is common with a project of this magnitude, the data transfer process required a certain number of iterations between the Team and the various utility personnel providing the data. Utility staff were cooperative and assisted us with sorting out the numerous issues arising from the data collection process.

However, it sometimes took two or three extra months to receive the data, and the final data transfers were sufficiently late that it put pressure on the Team to complete the report within the time frame. In addition, sometimes the data sets did not contain all of the requested fields, which made connecting the measure-, billing- and program-level data sets more complicated.

For example, in the preparation and delivery of the on-site survey in late 2006 and early 2007, data issues were identified that prompted the utilities to provide new data sets.

- SoCalGas discovered that the descriptions of the installed measure were reversed for heating system repair and replacement and that they had inadvertently omitted over 20% of their PY05 participants from the program- and measure-level data set. They provided new files in March of 2007.
- PG&E realized that they had not provided any measure-level data for space and water heating repairs and replacement. This supplemental data was provided in mid May, 2007.

A couple of specific parts of the data request were never completely fulfilled, and given the time frame, it was necessary to continue with the analysis without the data. SDG&E provided the aggregated CARE data only from March of 2004 to December of 2007, although our analysis period began in January of 2004. In the absence of this data, we extrapolated, using the daily changes in aggregate CARE consumption from the same calendar days in 2005 to adjust the 2004 values. SCE did not provide measure-level data for the PY2005 participants who received measures in PY2004.[13] This information was requested to avoid homes with unknown installations occurring throughout the analysis period, but the actual number of participants in this category was fairly small and thus, it

[13] They mistakenly provided the list of PY04 participants who received measures in PY2005, and since the household identifier changes from one year to the next, these participants could not be matched to the PY2005 list. Since this information was provided so late, there was no time to correct it.

was not worth delaying the analysis and report to obtain the actual data. Ultimately, however, these omissions turned out to be minor and unlikely to have had any impact on the reported savings.

4 Program Activity and Household Characteristics

The savings achieved by the program are directly related to the characteristics of the target population, as well as the specific interventions promoted through the program. Energy consumption patterns and length of tenancy at the location served by LIEE are both key factors that affect the magnitude and retention of program savings.

This chapter describes the program activity and characteristics of the LIEE households participating during PY2005. The first part of the chapter provides an overview of the program activity. The second section provides some information on the characteristics of the LIEE households, such as housing types, homeowner status, number of occupants and households led by a senior citizen. The third section describes the process for selecting the LIEE accounts to be included in the billing analysis, and the fourth section reviews the energy consumption patterns of these LIEE households. The final section provides an analysis of transience among the population, i.e., participants who may not have a long tenancy at the location served by the program.

4.1 Program Activity

Table 4-1 shows the total number of households served by LIEE in 2005 across California. The next four tables show the measures installed by housing type for the participating utilities. In total, 158,188 homes were served, with more than 49,000 receiving efficient refrigerators and more than 124,000 homes receiving weatherization services during PY2005.

Table 4-1: Statewide Summary of Program Activity

Measure Categories	Multi-family	Mobile Homes	Single Family	Unknown	Total
Refrigerators	11,321	4,793	31,490	1,455	49,049
Lighting Products (CFL's)	26,720	7,696	60,327	648	95,382
Water Heating	33,798	7,761	57,136	221	98,916
Air Sealing and Envelope	41,795	8,381	73,517	342	124,035
Heating System	231	420	7,706	0	8,357
Cooling Measures	446	505	4,292	6	5,249
Total Program Participants[14]	48,078	13,321	94,890	1,899	158,188
Average # of End Uses per Household	2.4	2.2	2.5	1.4	2.4

[14] 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 4-2: PG&E Summary of Program Activity by Household

Measure Categories	Multi-family	Mobile Homes	Single Family	Unknown	Total
Refrigerators	5,416	2,910	15,824	0	24,150
Lighting Products (CFL's)	14,308	5,241	33,456	0	53,005
Water Heating	13,232	4,556	30,238	0	48,026
Air Sealing and Envelope	13,120	4,911	32,646	0	50,677
Heating System	7	120	1085	0	1,212
Cooling Measures	404	170	1,908		2,482
Total Program Participants[15]	16,582	6,670	38,267	0	61,519
Average # of End Uses per Household	2.8	2.7	3.0		2.9

Table 4-3: SCE Summary of Program Activity by Household

Measure Categories	Multi-family	Mobile Homes	Single Family	Unknown	Total
Refrigerators	4,421	1,699	12,364	1,455	19,929
Lighting Products (CFL's)	8,180	2,190	19,847	648	30,856
Water Heating	507	7	75	221	810
Air Sealing and Envelope	586	7	105	342	1,040
Heating System					
Cooling Measures	42	326	2,382	6	2,756
Total Program Participants	10,091	3,181	26,226	1,899	41,397
Average # of End Uses per Household	1.4	1.3	1.3	1.4	1.3

Table 4-4: SoCalGas Summary of Program Activity by Household

Measure Categories	Multi-family	Mobile Homes	Single Family	Unknown	Total
Water Heating	16,588	3,013	20,719	0	40,320
Air Sealing and Envelope	16,528	3,002	20,718	0	40,248
Heating System	198	265	6,016		6,479
Total Program Participants	16,650	3,050	21,835	0	41,535
Average # of End Uses per Household	2.5	2.1	2.7		2.6

[15] 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 4-5: SDG&E Summary of Program Activity by Household

Measure Categories	Multi-Family	Mobile Homes	Single Family	Unknown	Total
Refrigerators	1,484	184	3,302	0	4,970
Lighting Products (CFLs)	4,232	265	7,024	0	11,521
Water Heating	3,526	195	6,111	0	9,832
Envelope	3,188	223	8,130	0	11,541
Heating System	26	35	605	0	666
Cooling Measures	0	9	2	0	11
Total Program Participants	4,755	420	8,562		12,737
Average # of End Uses per Household	2.6	2.2	2.9		2.8

4.2 LIEE Participants

There were 158,188 homes served by LIEE in 2005. Some characteristics of this population are described below.

- 69,123 (about 44%) were reported as owning their own homes and 88,132 as renters.
- 38,245 or 24% of LIEE households are occupied by senior citizens.
- 62% of seniors participating in the program are home owners and they account for 34% of all home owners in the program.
- 37% of the non-senior occupied LIEE households are homeowners.
- LIEE households are divided among the house types as follows: 31% live in multifamily dwellings, 61% in single family homes and 8% in mobile homes.
- 18% of heating systems in LIEE household were not working at the time of the energy assessment.
- 18,006 or 11% of LIEE households are headed by a member with some type of disability. 53% of the disabled are also seniors.
- The average income reported for LIEE households was slightly less than $17,000. For seniors it was slightly over $15,000.
- 42,258 homes (27%) had some type of working air conditioning.
- 37,851 (24%) LIEE households have only one occupant, and 37,617 (24%) have more than four members.
- 21,938 or 58% of the single person households are senior citizens.

4.3 Attrition in the Billing Analysis

Billing analyses require that the billing history of each participant be correctly matched to the program file, and that there be a sufficient billing history to cover the pre-program year, the program year, and the post-program year. Premises and accounts were removed from the analysis only for problems that would compromise the estimates of program savings. The focus was on removing threats to the analysis, while retaining as many participants as possible as a basis for estimating savings. The same set of LIEE accounts identified for inclusion in the billing analysis were also used to assess the consumption characteristics of the LIEE household, as described in Section 4.4 below.

The same process was used to identify the eligible accounts for both the electric and gas models. The total population was defined as those participants with measures expected to save the relevant fuel. For the electric installations, 114,378 participants were considered potential parts of the entire electric analysis. On the gas side, 99,212 program participants were considered potential gas model participants.

Following are the major reasons for removal:

- In this particular program year, new data fields were added to program files due to requests from the last evaluation. During the PY2002 evaluation, it was suggested that modeling would be much improved if information about whether energy-using equipment such as air conditioners and heating systems were used in the home rather than simply present. In some areas, these new data were not collected during the first quarter of 2005, and were therefore not available for analysis on participants who came into the program in the early months. This delay accounts for one of the larger data losses seen in Table 4-6 and Table 4-7, and these losses are categorized under the heading, Missing Program Data.
- Master-metered accounts include billing history for numerous living units. Since we would be unable to determine the total number of units on a meter, or the percent of residences that received treatment, it is not possible to teach out program impacts from the aggregate billing history.
- Insufficient or erratic billing history introduces a source of error into modeling efforts that would seriously compromise our ability to find savings. Premises and accounts that were eliminated for this reason sometimes showed no billing for several months in a row, or had less than a year of billing history before the program, usually due to account turnover, or some had unreasonably high bills, thus possibly indicating unrecognized master-metered accounts. High data error is especially important in this low-income population where savings are likely to be relatively small and difficult to detect.
- Other reasons for elimination included participation dates that did not match program limits, date inconsistencies, major installations that took place outside of the program date limits, and duplicate accounts or premises in the program file. Each of these problems created problems in defining clear program participation boundaries.

Table 4-6 shows the various reasons for removing premises from the analysis for the three electric utilities (PG&E, SDG&E, and SCE). This table shows that, of the original 114,378 participants, 39,825, or 35% could be retained for the electric billing analysis. At the premise level, by far the largest share of deletions came from insufficient billing data and missing program information. Some additional deletions were made at the account level; i.e., at the premise level the data were sufficient, but at the account level, there were problems that required removal. In almost all cases, the insufficient billing data was due to account turnover.

Table 4-6: Attrition from the Electric Model by Utility

	Combined Utilities	PG&E	SCE	SDG&E
Total Electric Premises	114,378	56,954	41,397	13,561
Reason for Elimination				
Missing Program Data	19,132	3,475	11,190	2,001
Insufficient/Erratic Billing	31,608	18,710	8,288	4,610
Master Metered	6,237	3,360	2,023	854
Other*	8,278	4,558	2,521	1,199
Eliminated at Account Level				
Insufficient or Erratic Billing	9,295	5,293	4,000	2
Master Metered	2	1	1	0
Other*	1	1	0	0
Accounts in the Final Analysis	39,825	21,556	13,374	4,895
Percent of Available Premises	35%	38%	32%	36%

*Includes date problems and inconsistencies, duplicate accounts or premises, and major installations outside of PY2005

Table 4-7 shows the same list of removal reasons for gas premises and accounts. Of the 118,098 potential model participants, 38,677, or 33% could be retained for analysis. The pattern of attrition for the gas participants is very similar to the electric. Most deletions were due to insufficient billing history or missing program data at the premise level. Further attrition occurred at the account level, mainly due to insufficient billing history, as was true of the electric participants.

Table 4-7: Attrition from the Gas Model by Utility

	Combined Utilities	PG&E	SCG	SDG&E
Total Gas Premises	99,212	48,929	39,859	10,424
Reason for Elimination				
Missing Program Data	11,406	6,829	2,498	2,079
Insufficient/Erratic Billing	33,911	15,454	14,516	3,941
Master Metered	8,171	2,050	5,126	995
Other*	2,558	1,350	865	343
Eliminated at Account Level				
Missing Program Data	181	181	0	0
Insufficient or Erratic Billing	4,301	4,299	0	2
Master Metered	5	5	0	0
Other*	2	2	0	0
Account in the Final Analysis	38,677	18,759	16,854	3,064
Percent of Available Premises	39%	38%	42%	29%

*Includes date problems and inconsistencies, duplicate entries, and major installations outside of PY2005

4.3.1 Comparing the Billing Analysis to the Original Population

The final accounts in the electric and gas billing models were compared to the original population of accounts to provide a picture of what biases may have resulted from the attrition described above. The comparisons were made based on the demographic characteristics that were available: housing type, senior citizens, renters/homeowners, and income.

A high percentage of mobile homes were eliminated (83% in the electric model and 87% for the gas model) due to the prevalence of master-metered mobile home parks. These eliminations resulted in 4% of the gas LIEE accounts being mobile homes, compared to the original population representation of 8%. Multifamily homes are better represented among the electric LIEE accounts at 22% compared to the population 27%. It naturally follows that single family residences are somewhat disproportionately represented at 74% of the LIEE accounts as compared to 64% of the population. In the gas model, the patterns are similar but a little stronger with multifamily homes comprising 22% of the LIEE accounts, and 31% of the population, and single family constituting 75% of the sample and 60% of the population. Methods to address these issues are discussed further in the following section.

Seniors' representation among the LIEE accounts and the population are similar at 29% and 23% respectively for the electric model and 36% versus 28% in the gas model. Again, the gas discrepancies between the LIEE accounts and population are a bit larger.

Renters are somewhat underrepresented in the model at 48% in the LIEE accounts, compared to 57% of the population in the electric model, and 41% versus 55% in the gas model. Naturally, the owners show the opposite pattern in both models.

As one would expect, a high percentage of both the LIEE accounts and the population had income in the lowest annual income categories of households with $22,000 or less. These households were 68% of the population and 65% of the LIEE accounts for the electric model, and 67% versus 63%, respectively, for the gas model.

4.4 Housing Types

When comparing the LIEE accounts used in the billing analysis to the total population of LIEE accounts, the biggest discrepancy arises with mobile homes. As described above, mobile home parks are generally master-metered and consequently, a high percentage of these homes were eliminated from the billing analysis, as also occurred in the previous evaluations based on billing analyses. In the process of planning for the PY2005 evaluation, we were asked to investigate methods to correct this imbalance.

To address this question, we assessed the possibility of obtaining submetered billing data for mobile homes. Our research indicated that this approach would be difficult, time-consuming and likely to restrict the sample size dramatically. According to another evaluator who pursued such a strategy, the submetered data can be hard to locate and is most frequently not kept in a consistent format; often it is not even available electronically.

The details of this assessment were documented in a memo to the SAT, which is included as Appendix F.
However, eliminating the possibility of submetered data for mobile homes does not provide any further insight into how to improve estimated by housing type. Accordingly, the Team investigated other avenues.

Based on the assumption that the weather-dependent measures are most affected by the housing, we decided to evaluate pre-installation heating and cooling loads by house type. Even with the high attrition among mobile homes, the billing analysis included more than 1,600 mobile homes, which is sufficient for this purpose. The average heating and cooling loads were then used to scale the savings for weather-sensitive measures by housing type.[16]

Other aspects of our analysis also facilitated the estimation of savings by housing types for non-weather dependent measures. Refrigerator savings were estimated by the pre-installation consumption level of the homes, which allowed for the scaling of savings based on the varying consumption levels among the housing types. Likewise, the savings from the DHW conservation package were estimated by the size of the household, supporting a similar scaling strategy.

4.5 Analysis of Energy Use

Consumption patterns are central to assessing potential savings. A home may well have a gas furnace, but if the participant does not use it, measures targeted at reducing space heating use will not generate the anticipated savings. Thus, the level of consumption in LIEE homes is likely to have a major impact on the magnitude of the program savings. An analysis of the usage characteristics of the LIEE accounts, in combination with the participant-level information collected through the on-site surveys, provides insight into the potential savings in LIEE homes.

Examination of the billing records indicate that, in general, LIEE households use less energy (both gas and electricity) than the average residential customer, although the consumption levels are in line with the low income market sector. For electricity, the saturation of high-use heating and cooling equipment is lower than the general population, suggesting that potential savings are limited. While the prevalence of gas space and water heating devices is higher among LIEE participants, average gas consumption is lower, indicating that this population uses less for these critical end uses than other residential customers.

These findings from the billing records dovetail nicely with the results of the on-site analysis. Almost half of the surveyed participants indicate that they do not use their heating systems or use them for less than 30 days per year. The mild climate in the heavily

[16] We initially considered conducting a two-stage analysis in which the weather-normalized output from the regression-based heating and cooling analysis is used for a second regression that estimates measure impacts. After further debate, this strategy was not pursued, largely due to concerns that the two-stage approach reduces the available data by collapsing all of the billing to one record per home and restricts the ability of the analyst to assess and mitigate violations of the ordinary least squares analysis, such as non-normal distribution of residuals, autocorrelation and heteroskedasticity.

populated areas of California is definitely a factor in heating use, as shown by the fact that the percent of homes with minimal heating use is higher in the more temperate regions. (Please refer to Table 8-7 for more details.) Many LIEE participants reported voluntarily taking steps to reduce energy consumption. Even the self-reported hours of use for lighting are lower than found in other studies.[17]

To gain further insights into these issues, the pre-installation billing data was analyzed for the group of participant accounts used in the final electric and gas models. Consequently, the composition of the group is affected by the filters that have been employed for selecting accounts for analysis. For instance, households on master-metered accounts are not represented, and premises that have had a turnover in occupancy during the three-year analysis period are underrepresented. The following discussion is based on the set of accounts used in the billing analysis, as described above. This subset of participants is referred to as "LIEE accounts." The phrase "LIEE households" is used to refer to the total population of PY2005 participants.

4.5.1 Electricity Consumption and Potential Savings

This analysis of the LIEE account suggests that LIEE households consume less electricity than the average residential customer. The mean annual consumption for the LIEE accounts prior to participation in the 2005 LIEE program was 5,431 kWh. In comparison, the statewide data for California shows an average electricity use of 4,551 kWh for customers who earn less than $25,000 a year and 5,129 kWh for customers with incomes between $25,000 to $35,000.[18] In contrast, the average consumption for residential customers is 6,029 kWh, or about 15% higher than the mean LIEE consumption.

Table 4-8: Annual kWh Statistics by Electric Heating and Cooling Equipment

Equipment	N	Mean kWh	Median kWh	25th Percentile kWh	75th Percentile kWh
Overall	39,825	5,431	4,665	3,124	6,859
Central A/C[19]	9,174	6,885	6,069	4,166	8,599
Room A/C	4,206	5,408	4,559	3,045	6,780
Electric Space Heat	3,621	6,267	4,811	2,742	8,312
Electric Water Heat	2,121	8,837	7,640	4,886	11,540

[17] CFL Metering Study Final Report. Prepared for Pacific Gas & Electric Company, San Diego Gas & Electric Company and Southern California Edison. Prepared by KEMA Inc., Oakland California. February 25, 2005, page 1-5.

[18] All statewide statistics used in this section are from the California Statewide Residential Appliance Saturation Survey (KEMA-XENERGY, Itron, and RoperASW, 2004).

[19] Participant counts for air conditioning and space heat include only those who were identified as having working systems at the time of the energy assessment.

Table 4-8 shows kWh use of the LIEE accounts overall and for homes with electric heating and cooling equipment.[20] Households with electric water heating, central air conditioning or electric space heating have higher than average kWh consumption. However, only about 5%, 23% and 10% of the LIEE accounts have this equipment, respectively.[21] Thus, with the exception of refrigerators, a substantial portion of the LIEE households do not have any electric heating or cooling equipment, suggesting that there may not be a large potential for electric savings in many LIEE households.

From this analysis, it appears that electric water heating and central air conditioning are the two largest drivers of electricity consumption. Among the LIEE accounts, the percentage of working CAC systems is about 27%, whereas a conservative estimate for statewide saturation is 35%. About 4% of LIEE households use electric water heating compared to 8% statewide.

While the differences may not be dramatic, together these two factors point to the fact that LIEE participants have less high-use equipment in their dwellings than the average customer. Since these appliances have the most potential for savings, and there are fewer of them among LIEE household, the potential for savings is lower than it otherwise would be.

Another way to look at consumption is by housing type and demographic characteristics that can affect consumption. Table 4-9 displays those characteristics available for analysis that could impact consumption, and thus hold potential for savings by energy-efficient installations.

Table 4-9: Annual KWh Statistics by Housing Type and Demographics

Characteristic	N	Mean	Median	25th Percentile	75th Percentile
Overall	39,825	5,431	4,665	3,124	6,859
Multifamily Housing	8,880	3,738	3,163	2,223	4,577
Mobile Home	1,630	6,565	5,327	3,714	8,086
Renting	18,990	4,539	3,770	2,543	5,639
Senior Head of Household	11,406	5,176	4,278	2,767	6,579
Income < $22,000	23,667	5,246	4,447	2,936	6,639
Lives Alone	10,643	4,484	3,692	2,423	5,618

An analysis of housing types shows that living in multifamily housing is associated with low electric use, although less than 25% of the LIEE accounts falls into that category. In addition, living alone has a downward impact on consumption, and describes about 30% of the LIEE accounts in the analysis.

[20] This analysis was completed at the account level.
[21] the percentages mentioned here are based on the valid values available on each variable, not necessarily on the total number (e.g., 40,981 for Table XX-X1, shown on the first row of the tables)

Although a minority of LIEE accounts fall into any single group, an analysis of the three categories associated with the lowest consumption (multifamily, renting, and living alone) shows that almost 70% of the accounts fall into at least one of these low-consumption categories, and 33% fall into two or three of them. Thus, a substantial proportion of the LIEE accounts fall into very low consumption categories, indicating that there is less potential for substantial savings among this segment of the population.

4.5.2 Gas Consumption and Potential Savings

Similar analyses were completed for gas consumption, as shown in Table 4-10 and 4-11. The mean annual therm consumption for the PY2005 households represented in the billing analysis was 421 therms, about 9% lower than the statewide average of 460 therms. Among low income residents, the average gas use is 369 therms in homes with incomes less than $25,000, and 398 therms for customers with incomes between $25,000 and $35,000.

In terms of gas heating equipment, LIEE households are considerably more homogeneous than was found in the analysis of electric accounts. For most LIEE accounts, the difference in consumption associated with the presence of each equipment type is small. More importantly, most gas customers have working systems (98% have gas water heating, and 85% have working gas space heating), making gas savings somewhat more likely than electric. However, it is also interesting to note that the LIEE homes have both a higher saturation of gas space and water heating *and* lower than average annual gas consumption, suggesting that occupants of LIEE homes are more frugal than the average residential customer.

Table 4-10: Annual Therm Statistics by Gas Heating Equipment

Equipment	N	Mean	Median	25th Percentile	75th Percentile
Overall	38,629	421	395	264	542
Gas Space Heat[22]	32,680	427	399	267	550
Gas Water Heat	37,695	421	395	264	542

While the previous analysis showed that LIEE accounts have less electric heating and cooling equipment than is found statewide, the opposite is true for gas equipment. At the statewide level, 73% of homes use gas space heating, as compared to 98% of the LIEE accounts (although only 85% have working equipment). Statewide, 72% have gas water heating, while 98% of LIEE accounts have it. These results suggest there may be greater potential savings from energy-efficient gas equipment than from improving electric efficiency.

[22] These homes all have working gas space heating.

Table 4-11 shows that living in multifamily housing has the biggest downward impact on consumption of all the listed characteristics, and 31% of all LIEE households live in multifamily housing. Renters tend to use less on average than homeowners, and renters constitute a small majority of all LIEE households (56%). Of these characteristics, only multifamily homes and renters are associated with a 20% or more reduction in consumption. About 57% of all LIEE households belong to either one or both of these categories, and 30% fall into both.

Table 4-11: Annual Therm Statistics by Household Characteristics

	N	Mean	Median	25th Percentile	75th Percentile
Overall	38,629	421	395	264	542
Multifamily Housing	8,581	246	221	114	333
Mobile Home	1,184	481	454	355	569
Renting	15,863	335	299	178	450
Senior Head of Household	13,723	453	420	285	576
Income < $22,000	24,209	412	383	248	536
Lives Alone	10,151	402	368	230	522

In summary, there is greater homogeneity in gas heating equipment among LIEE participants than was found for electric equipment, and there are fewer households with characteristics associated with reduce consumption. These factors suggest that there is more potential for savings with gas than electricity customers. However, given the mild heating climate prevalent in many parts of California, it seems reasonable to assume that gas savings would be lower than seen in the evaluations of programs delivered in other parts of the country.

4.6 Turnover Rates among LIEE Participants

Another concern is the length of tenancy at the location served by the program. When participants move to another location, the impacts on the energy savings are unknown. Participants who learned from the energy education may well take this knowledge, as well as CFL's or easily portable items, on to their next home, , and the next tenant will benefit from the more permanent measures. Thus, moving from the original site does not necessarily correspond to lower savings, although it is possible the savings could be moving to another utility's service territory.

The savings estimates presented in this study were developed from surveys and analysis of LIEE participants who remained at the original address. The on-site survey was designed to interview those parties who actually participated in the program and received the energy education, and the billing analysis removed all accounts that did not have two consecutive years' worth of billing records. Since the savings impacts related to participants who move to other locations are unknown, the analysis in this section is intended to provide some indication of the potential scope of the issue.

The analysis of turnover rates was completed for both electric and gas premises for all billing data provided by the utilities, including accounts that were eliminated from the billing analysis due to incomplete billing or other screening criteria. The number of unique account numbers associated with each premise was taken to represent the number of changes in occupancy for the premise. The number of changes in a premise was categorized into four groups: none (no turnover), one change in occupancy, two changes, and three or more changes. These levels of turnover were then analyzed by housing type, rent/own status, and CARE rate use. Each analysis is presented by utility.

Overall, based on Table 4-12 and Table 4-13, there was at least one turnover in approximately 30-35% of the premises in this analysis, with the exception of SDG&E where the extremely low (virtually 0%) turnover rate suggests that there may be a problem with the data.

Table 4-12: Turnover Rate in Program Electric Accounts by Utility

	Combined Utilities		PG&E		SCE		SDG&E	
Account Turnovers	# of Premises	% of Total	# of Premises	% of Total	# of Premises	% of Total	# of Premises	% of Total
None	68,404	69.1%	33,302	64.9%	23,029	64.7%	12,073	99.8%
One	16,036	16.2%	9,436	18.4%	6,577	18.5%	23	0.2%
Two	9,210	9.3%	5,385	10.5%	3,824	10.7%	1	0.0%
Three or more	5,330	5.4%	3,156	6.2%	2,174	6.1%	0	0.0%
Total	98,980		51,279		35,604		12,097	

Table 4-13: Overall Turnover Rate in Program Gas Accounts by Utility

	Combined Utilities		PG&E		SoCalGas		SDG&E	
Account Turnovers	# of Premises	% of Total	# of Premises	% of Total	# of Premises	% of Total	# of Premises	% of Total
None	65,090	73.9%	28,659	67.7%	26,800	74.2%	9,631	99.7%
One	17,848	20.3%	10,700	25.3%	7,116	19.7%	32	0.3%
Two	4,522	5.1%	2,917	6.9%	1,605	4.4%	0	0.0%
Three or more	673	0.8%	70	0.2%	603	1.7%	0	0.0%
Total	88,133		42,346		36,124		9,663	

As may be expected, turnover rates are higher in multifamily units than single family or mobile homes, by about 40% as compared to 23 to 27%. Similarly, those who own homes are less likely to move than renters (Table 4-14 to 4-16). SDG&E is excluded from

Table 4-14These tables due to concerns that the data does not accurately reflect the participant turnover.

Table 4-14: Electric Premise Account Turnover by Own/Rent Status

	All Premises	Rented	Owned
Total # Premises	98,215	50,091	36,036
% of Premises with Turnovers			
None	69.1%	53.0%	81.2%
One	16.2%	21.3%	14.5%
Two	9.3%	15.7%	3.4%
Three or more	5.4%	9.9%	0.9%

Table 4-15: Gas Premise Account Turnover by Own/Rent Status

	All Premises	Rented	Owned
Total # Premises	78,460	41,051	37,409
% of Premises with Turnovers			
None	70.7%	60.7%	81.6%
One	22.7%	28.5%	16.4%
Two	5.8%	9.3%	1.8%
Three or more	0.9%	1.5%	0.2%

The largest effect on turnover rates appears to be associated with those low-income participants who are on the CARE rate (Table 4-16 and Table 4-17). Those who are on the CARE rate have a much lower turnover rate (about 25%) than those who are not on the CARE rate (approximately 60%).[23]

Table 4-16: Electric Premise Account Turnover by CARE Rate Status

	All Premises	On CARE	Not On CARE
Total # Premises	86,883	70,159	16,724
% of Premises with Turnovers			
None	64.8%	71.7%	36.0%
One	18.4%	16.1%	28.3%
Two	10.6%	8.4%	19.9%
Three or more	6.1%	3.8%	15.8%

[23] The CARE rate analysis was based on the rate in use at the premise at the time of the first meter read in our dataset. Thus, a premise is counted as on the CARE rate if the occupant was on that rate when our database begins and the rate at that time is predicting the turnover rate over the subsequent three years.

Table 4-17: Gas Premise Account Turnover by CARE Rate Status

	All Premises	On CARE	Not On CARE
Total # Premises	78,470	63,510	14,960
% of Premises with Turnovers			
None	70.7%	78.1%	39.0%
One	22.7%	17.7%	44.1%
Two	5.8%	3.7%	14.6%
Three or more	0.9%	0.5%	2.3%

5 Energy Education and Program Implementation Issues

This chapter provides an overview of our qualitative assessment of the energy education component of the program. The second section discusses issues related to program implementation that arose as a by-product of our impact evaluation activities.

5.1 Energy Education

Assessing the impacts of energy education is a complex task that depends largely on the memory of the survey respondent. As part of the on-site assessment performed for this evaluation, we surveyed the home occupant most familiar with the program. Part of that survey included a battery of questions on the energy education component. Issues associated with fielding this component of the survey, interpreting the results and weighting by auditor are described in more detail in the full On-site report, Section 2, Methods, attached as Appendix D.

To support the analysis of the energy education interview, we also compared the participants' responses to data collected from other parts of the survey for the purpose of verifying that the responses were reasonable. This analysis is presented in Section 5.1.2, Alternative Perspectives, below. In the following section, the LIEE results are compared to a couple of other residential programs where energy education impacts were evaluated. This discussion is followed by a summary of the energy education results.

5.1.1 The Energy Education Interview

As can be seen in Table 5-1, about 27% (270/1000) of the participating households recall ed that the LIEE program staff discussed the savings associated with specific measures installed in their homes. In response to a separate question, 37% of the surveyed participants recalled receiving recommendations for reducing household energy consumption by incorporating conservation practices into their day-to-day activities.

Table 5-1: Households Recollecting EE Information Provided by LIEE

Recollecting that the LIEE Program provided information on …	Frequency (out of 1000 homes)
Energy savings from the installed items	270
How much energy is used for different purposes	239
How to reduce your energy use	372

Table 5-2 gives a summary of the number of homes who reported taking conservation actions within the last two years and attributed those actions to a utility program. This overview indicates that LIEE participants are likely to be taking conservation actions even prior to participating in the program, and those participants who recalled the LIEE energy education substantially increased their conservation actions.

Table 5-2: Summary of Homes Taking Conservation Actions

	Recollection status		
	Recalled LIEE Energy Education	Did not Recall LIEE Energy Education	Totals
Total # of homes[24]	372	622	994
# of homes adopting energy conservation action(s)	364	502	866
# of homes with action(s) attributed to a "Utility Program"	246	59	305
% of homes with action(s) attributed to a "Utility Program"	66%	9%	31%
Total # of actions taken per home on average	3.7	2.1	2.7
# of actions with no attribution to a "Utility Program"	1.8	1.9	1.9
Average # actions per home attributed to a "Utility Program"	1.9	0.2	0.8

This table supports a number of findings:

- 31% of LIEE homes attributed one or more conservation actions to a "utility program." Among homes who recalled receiving the LIEE energy education, this percentage doubles to 66%. These actions were distributed over a range of end uses with reducing lighting being the most frequently reported. (See Figure 5-1.)
- LIEE homes on average engaged in about 1.9 conservation actions that are not associated with the program.
- Participants who recalled the energy education reported almost twice as many conservation actions as those who did not recall this component of the program (3.7 as compared to 2.1).

These results suggest that the energy education is reaching about a third of participants, and that these participants have made changes to their energy practices as a result of the energy education.

Table 5-3 shows the actions mentioned by the occupants by the timing and attribution to LIEE, and Figure 5-1 illustrates the trends in graphical format. The percentages of homes with the action are presented in the table, and the number of homes per 1,000 can be estimated from the graph. If an action was started within the last two years and attributed

[24] The auditors were unable to administer the survey in three homes due to language barriers.

to a "utility program" or the action was mentioned when the auditor specifically asked about the LIEE program, it was assumed to be related to the LIEE Program.[25]

As discussed under Data Collection in the full report, some mild prompting was offered by the auditor to jog the respondent's memory. The auditors were instructed to mention only the end use (such as lighting or hot water), but not to list specific actions. For the actions listed in regular type face, most of the homes needed some prompting, with volunteered responses accounting for about 10% to 40% of the homes in these categories. The actions listed in italics were offered without prompting by over two-thirds of the survey respondents who mentioned the specified item.

Table 5-3: Conservation Actions by Timing and Program Attribution[26]

Timing	**Started Over Two Years Ago**	**Started Within Two Years**	**Started Within Two Years**	**All Homes with Action**
Attribution Status	**Not LIEE**	**Not LIEE**	**LIEE**	**All Homes**
Action Taken	% of All Homes with the Action	% of All Homes with the Action	% of All Homes with the Action	# Homes per 1,000
Reduce lighting use/turn off lights	66%	7%	27%	849
Lower T-stat/use heat as needed	72%	5%	22%	528
Lower DHW temperature	53%	7%	41%	187
*Wash/dry with full load**	*44%*	*4%*	*52%*	*170*
Keep refrigerator full	58%	6%	35%	154
Raise T-stat/use A/C as needed	60%	7%	33%	135
Wash with cold water	57%	3%	39%	104
Don't heat/cool unused rooms	59%	7%	34%	86
Buy CFL's	12%	14%	74%	61
*Reduce cooking use**[27]	*78%*	*14%*	*8%*	*32*
*Shade windows to keep house cool**	*5%*	*8%*	*87%*	*31*
*Dry clothes on line/rack**	*30%*	*24%*	*46%*	*10*

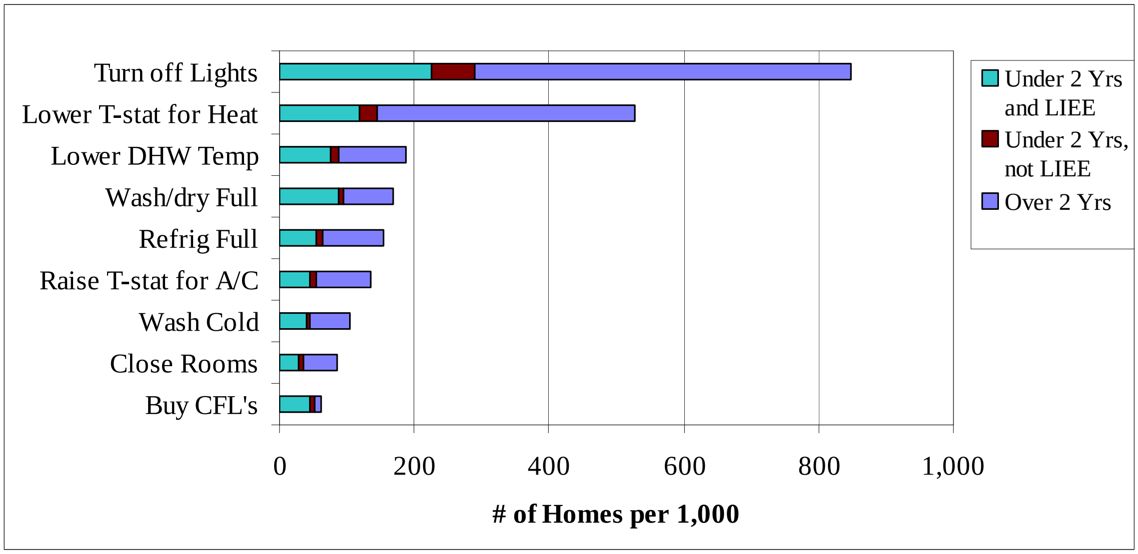
* *Over two-thirds of the survey respondents with this action identified it without any prompting from the auditor.*

[25] The question that specifically referred to the LIEE program was asked last, and very few additional actions were identified in that manner.

[26] Other items were also mentioned at a much lower incidence rate. These include using the refrigerator energy switch (0,9% of homes), having the heating system tuned and installing evaporative coolers ((0.7% each), using fans for cooling (0.3%), cleaning filters (0.2%), avoiding A/C use and installing double pane windows (0.1% each).

[27] Reducing cooking use included covering pots, turning down pots when they reach the boiling point, defrosting food before cooking and using the microwave whenever possible.

Figure 5-1: Graph of Conservation Actions by Timing and Program Attribution



This analysis shows that many LIEE participants are energy-conscious and engage in a variety of conservation actions, even without encouragement from LIEE delivery contractors. The green part of the bar in Figure 5-1 indicates the homes with the action that were likely to be associated with the LIEE program; the (small) brown section indicates homes in which the action started within the last two years but was not attributed to a utility program, and the blue part of the bars shows the homes who started the action over two years ago.

A few findings that can be drawn from this analysis are outlined below.

- For most actions, a substantial majority (56% to 78%) of survey respondents with the action claimed to have initiated the specific conservation practice more than two years ago.
- When considering those who started the action within the last two years, the utility program is consistently identified as the primary source of information for a high proportion of these homes.
- The two actions with the highest penetration, i.e., turning off lights (84%) and lowering the thermostat for heating (51%), were associated with the LIEE Program by about one-quarter or fewer of the homes taking the action.
- The actions with the highest attribution to LIEE, such as keeping shades down and buying CFL’s, have a low overall incidence of acceptance (3 and 5%, respectively) according to the responses to the energy education questions.
- The actions recalled by the survey respondents range from those that may result in significant reductions in use, such as lowering the thermostat for heating or drying clothes on the line instead of the clothes dryer, to practices that are likely to have little actual impact on energy use, such as keeping the refrigerator full.

5.1.2 Alternative Perspectives

Given the myriad difficulties in obtaining accurate information regarding the impacts of energy education, we reviewed some of the other information collected through the on-site survey for insights into this component of the study. Our review of the actions taken and other data collected suggested three avenues to explore.

1) The lighting inventory listed all CFL's with the source, allowing us to identify CFL's that were purchased by the participants.
2) Some participants indicated that they had lowered the thermostat on the DHW tanks, and the auditors recorded the maximum water temperature at the kitchen tap.
3) A number of energy conservation practices relate to reducing cooling use, and we collected a comprehensive list of cooling equipment found in the home.

This additional information can be used to verify that the energy practices identified by the participants are reasonable given the specific conditions in the home, and also to assess whether some conservation practices may have been omitted by a large group of participants. While this approach may allow us to identify underreporting of some of conservation practices in general, it will not provide any insight into the role of the LIEE in encouraging energy conservation,

The first question was whether the participants' responses were reasonable within the context of the other information collected at the site. Table 5-3 lists the actions, the percent of homes with the action where the action could be verified, the method of verification and related issues.

Table 5-4: Verification of Some Conservation Actions

Action	% Verified	Method of Verification	Issue(s)
Buy CFL's	75%	Found at least one CFL on the lighting inventory marked as a customer purchase	CFL's could have been located in unusual places, such as closets, and missed by the auditor
Lower DHW Tank Temperature	78%	DHW temperature at the kitchen tap measured at 130º or less	Original temperature is unknown and could have been substantially higher or lower than 130º
Raised T-stat for cooling	88%	Homes with a cooling system	Action not directly verified, but presence of cooling system indicates that the action could be taken

This analysis suggests that most of the participants provided reliable responses for these three conservation actions.

The next stage looked at the question from the opposite angle: are there many participants who have taken specific conservation actions but did not mention them during the energy education interview? The following findings provide some additional information associated with this issue.

- Almost 40% of the survey respondents have CFL's that were marked as customer purchases on the lighting inventory, but only 5% identified buying CFL's as a conservation practice that they are currently using.
- About 4% of the survey respondents mentioned purchasing CFL's in the energy education component and associated the action with a utility program. These households had twice as many customer-purchased CFL's on average than those who did not recall the recommendation to buy CFL's. (See Table 5-4 below.)
- The DHW tank temperature at over 60% of the surveyed homes was 125ºF or less, but only 17% identified lowering the tank temperature as a conservation action they had taken. (Some of the lower tank temperatures may be due to malfunctioning equipment or factors other than energy conservation practices.)
- Although 6% of the survey respondents had an evaporative cooler and a refrigerant-based A/C system, less than 1% mentioned the evaporative cooler as an energy conservation action.

Table 5-5: Relationship between Energy Education and Purchase of CFL's

The participant …	Mean # of Lamps Purchased by Participant	Number of Homes (per 1,000)
Did *not* recall learning about buying CFLs	1.56	957
Did recall learning about buying CFLs	3.68	43
Grand Mean	1.66	

Significant at < 0.001

These findings suggest that the total incidence of energy conservation practices may be underreported in the energy education interview. It is not possible to determine whether any of these potentially underreported actions can be attributed to the LIEE program.

5.1.3 Comparison to other Energy Education Efforts

We also reviewed other energy education efforts for comparison purposes. The Home Energy Efficiency Services (HEES) Program offers Internet and direct-mail audits to interested participants, who receive an audit report and recommendations for both measures and practices. The evaluation for PY 2002 found that participants had adopted an average of 0.7 of the practices recommended in the audit reports.[28] Unlike our on-site survey, these survey respondents were asked directly if they had pursued each of the HEES recommendations.

[28] Final Report for the Evaluation of the California 2002 Home Energy Efficiency Survey Program, June 2004. Ridge & Associates, In association with KVD Research Consulting and Quantum Consulting (http://www.calmac.org/publications/HEES_PY_2002_Final_Report.pdf), pages 4-27 to 4-29.

In comparison, LIEE survey respondents identified 0.8 actions attributable to the program, which is close to the HEES results. While one would expect that an in-home audit, such as offered through LIEE, allows the opportunity to build rapport and trust with the participant and would result in higher rate of follow through, it is also entirely possible that direct questioning as used in the HEES study would have yielded more positive responses among the LIEE respondents.

In a follow-up survey for PY 2004-2005, about 60% of HEES participants stated that they had followed at least one recommendation and 38% responded that their decision was at least partly influenced by the program.[29] The HEES recommendations included both measures and practices, and the adoption rates were not broken out. An evaluation of the SDG&E Residential In-Home Audits Program found that 65% of the participants reported making a behavioral change in response to the programs.[30] In this study, the questions were also directly tied to the program. The LIEE adoption rate for conservation practices is closer to one third of participants, somewhat lower than either of these two programs.

While the evaluation results of these other programs seem to suggest greater impacts for the energy education component than found in our on-site survey, it is also important to keep in mind a number of possibly extenuating factors:

- The participants in these other residential audit programs are self selected in that they choose to participate in the program and may be more oriented toward learning new strategies for saving energy. While there are numerous ways to enroll in the LIEE Program, at least some participants are solicited through canvassing by program contractors, rather than directly contacting the utility for services.
- The results of our survey indicate that many LIEE participants are highly motivated to reduce energy bills prior to program services, which may also affect the acceptance of additional recommendations for behavioral modifications.
- The methodology of the evaluation may have an effect on the results. The two other evaluation studies directly questioned respondents about program recommendations, while the LIEE survey relied largely on general prompts related to the end use.

Thus, it is possible that some of the differences in the reported energy education impacts could be related to differences in methodology, program implementation and the composition of the target population.

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[29] Process Evaluation For The 2004-2005 Statewide Home Energy Efficiency Survey Program (HEES), January 2007. Prepared by Opinion Dynamics Corporation. Subcontractors Lori Megdal, Megdal & Associates, Craig Williamson, EPRI Solutions (http://www.calmac.org/publications/04-05_Statewide_HEES_Process.pdf)

[30] Measurement and Evaluation Study of the 2003 SDG&E Residential In-Home Audits Program**,** August 2004. Prepared by RLW Analytics, Inc. (http://www.calmac.org/publications/2003_Sempra_In-Home_Audits_EMV_Report_FINAL.pdf)

5.1.4 Summary and Comments on the Energy Education Component

The various elements of this analysis point to the conclusion that this population tends to be conservation-minded and is likely to be engaging in at least some energy conservation practices prior to program participation. Nonetheless, about a third of participants recall at least some of the recommendations made by LIEE staff and have taken action to reduce their use further.

For those few who recalled and implemented some of the less popular actions, such as pulling down shades and drying clothes on the line, the high attribution to LIEE suggests that this information may not be readily accessible from other sources and the program is providing a valuable resource to participants. Increasing the emphasis on these relatively uncommon actions with the potential for significant savings may be worthwhile.

A comparison to evaluations of two other residential programs indicates that the LIEE program is less effective at promoting energy conservation practices than these other programs, but this conclusion may be partly based on differences in participant characteristics, methodology and program implementation.

Reviewing relevant information from other components of the on-site survey suggests that it is possible the overall incidence of some conservation practices is actually higher than reported, but we could not ascertain whether this underreporting extends to the LIEE-attributed actions.

5.2 Program Delivery Issues

While our primary focus is impact evaluation, information was collected through the implementation of the showerhead and on-site surveys that may be useful to program staff. These issues are organized according to the source of the information, starting with the relevant results from the showerhead survey and followed by the issues identified through the on-site survey.

5.2.1 Showerhead Survey

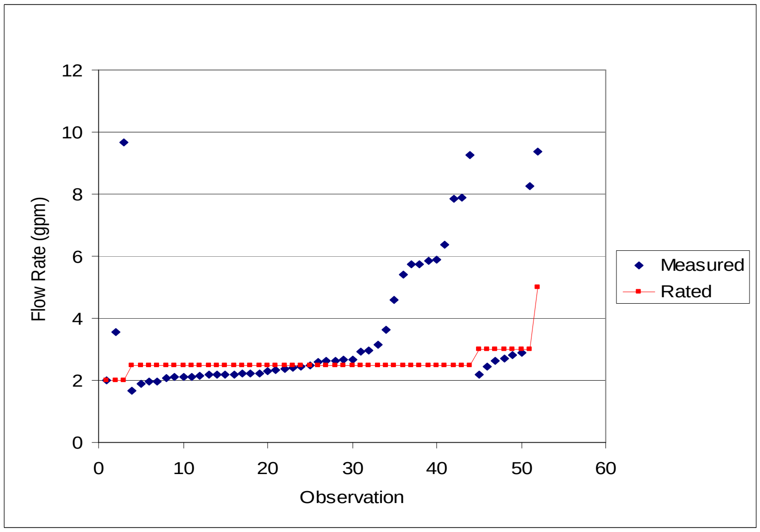
Three of the findings from the showerhead survey have possible implications for program implementation:

- The listed flow rate on the outside of the fitting (when available) is not necessarily a good indicator of the measure's flow rate, suggesting that identifying showerheads with a flow rate above 3.0 gpm is not a simple task.
- Some fittings are restricted by mineral deposits and others with signs of mineral deposits have been modified to allow for increased flow.
- The flow rates for the replacement, low flow showerheads are more variable than would be expected.

Each of these topics is explored in more detail below.

According to LIEE protocols, showerheads should be replaced if they have a flow rate greater than 3.0 gpm, and the new, replacement fittings must use 2.5 gpm or less at 80 psi.[31] The absence of listed flow rates for some showerheads and the lack of a strong correlation between the listed flow rates (where available) and actual tested values suggest that identifying showerheads meeting the LIEE criterion is not a straightforward task. Direct measurement of the flow rate may be the only reliable method of identifying those fittings that meet the LIEE standard for replacement. Figure 5-2 below shows the relationship between the ratings listed on the fittings and the measured flow rates.

Figure 5-2: Measure v Rated Flows by Showerhead[32]



A few of the devices had very low flow rates, possibly due to mineral build up that plugs the holes. Although technically these devices do not meet the program protocols for replacement and removing them will not achieve immediate savings, leaving them in place may not be the best long-term solution. Through visual inspection, we found that a number of showerheads had been modified by removal of the flow restrictors, indicating that excessively low flow rates could be problematic and lead to actions ultimately resulting in increased water and energy use. Thus, it may well be worthwhile to replace or clear deposits from these extremely low flow devices, both from the perspective of participant comfort and preventing future modifications to the plumbing fittings.

The results of the showerhead survey further suggest that the flow rates for the replacement, low flow fittings are more variable than expected. Six of the contractors provided examples of the low flow devices they install through the program, for a total of thirteen showerheads and six aerators.[33] Four of the thirteen showerheads had tested flow

[31] "California Statewide LIEE Policies and Procedures Manual," December, 2003, page 7-12.
[32] This part of the analysis was restricted to unadjustable showerheads, since the testing results for the adjustable ones may reflect the specific settings chosen by the homeowner, leading to a situation in which a tested value substantially lower than the rated one may be due to individual preferences rather than the characteristics of the showerhead itself.
[33] All six sent in showerheads, but only two contractors provided aerators.

rates between 2.5 and 3.0 gpm at 80 psi, and one adjustable showerhead had a maximum flow rate of 4.5 gpm. In addition, seven of the thirteen tested below 2.0 at 40 psi.[34] A tested flow rate above the LIEE requirement of 2.5 gpm at 80 psi was recorded for one of the six aerators. These results suggest that there may be quality concerns regarding the new products installed.

5.2.2 On-Site Survey

Some of the findings that may be relevant for program implementation are listed below.

- The energy education component of the study found some conservation actions with high potential savings, such as pulling down shades to reduce cooling use, had a low overall incidence and high attribution rate to LIEE, suggesting that focusing on recommendations with higher savings and lower acceptance may improve the impacts of this program component.
- About 35% of the LIEE-installed CFLs failed, had been removed or were never installed. This low persistence rate of the CFLs is a matter of concern, as well as 8% of program participants who responded that the CFLs were not actually installed. Improving the quality of the CFL lamps and ensuring their installation are small steps that could help boost program savings.
- The retention rate for showerheads and aerators was 80%, leaving substantial room for improvement.
- About 35% of the homes with LIEE evaporative coolers report that they do not always have a window open when the unit is operating, suggesting that education about the proper use of the cooling equipment is another worthwhile area to explore.
- Approximately 10% of LIEE household own a secondary refrigerator or freezer. Consequently, it may be worthwhile to incorporate information about the savings related to the retirement of secondary refrigerators into the energy education component and consider referring these participants to other utility or municipal efforts to collect secondary refrigeration equipment.

While not a primary objective of this study, these findings may provide useful feedback to program implementers.

[34] LIEE installation standard require that the replacement low flow showerheads have a maximum flow rate of 2.5 at 80 psi and a minimum of 2.0 at 40 psi.

6 Model Selection and Regression Theory

This chapter covers the theory behind the model selection and regression methods. The specifics of the application of the theory are discussed in the following chapter. References are provided at the end of this chapter.

One aspect of this analysis that is different from previous evaluations, and sets it apart from other impact evaluations, is the application of an innovative strategy for model selection. Specific modeling decisions can have a major impact on the results of the analysis, and variations in methodology, ranging from structure of the model to the types and content of included variables, can be nearly as numerous as the individuals performing the analysis. Without a clear and objective standard for identifying the "best" model, the researcher is left in the position of making a decision based on his or her judgment and lacks a strong foundation to support the choice of models. The information-theoretic approach provides the framework for conducting selecting the models.

The second section of this chapter outlines the theoretical underpinnings of the fixed effects models used in this analysis. Fixed effect models have been shown to be an effective tool for the estimation of savings from cross-sectional time-series (CSTS) models and are among the methods recommended in the California Evaluation Framework.[35]

6.1 Model Selection Theory

The goal of model selection is to find the most parsimonious model, i.e., the simplest model that adequately fits the data. Underfit models, i.e., those with too few variables or model terms, will tend to produce biased estimators, whereas overfit models will lead to a lack of precision of the estimators. Akaike's Information Criterion (AIC) is gaining popularity as a tool for model selection and has been shown to perform well in balancing between these competing objectives (Burnham and Anderson 2001:35-37, Kmeta 1980, McQuarrie and Tsai 1998).

This strategy of developing a parsimonious model using the AIC creates a powerful tool for developing robust and defensible estimates of the impacts from energy efficiency programs. One favorable aspect of the AIC is that it incorporates a penalty for adding variables, creating a situation in which the improvement in fit to the model must outweigh the negatives associated with expanding the variable list.

While the purpose of moving toward an objective standard for model selection is to avoid results-based decisions, no method completely substitutes for the judgment and experience of the researcher. Rigid adherence to any set of rules can easily run afoul of basic common sense, and all results should be assessed within the context of other research in the field and the knowledge of the analyst.

[35] TecMarket Works, et. al. The California Evaluation Framework. Project Number: K2033910. Prepared for the California Public Utilities Commission and the Project Advisory Group. June, 2004.

6.1.1 Information-Theoretic Approach

The information-theoretic approach is designed to allow a group of candidate models to be compared and ranked by use of Akaike's Information Criterion (AIC). The model with the lowest value of the AIC is the one that best fits the data set, i.e., the model that minimizes the information loss. Only logistics and common sense limit the number of models that can be compared.

The AIC is calculated from the log likelihood function with an added penalty reflecting the number of parameters in the model, as shown below:

$$AIC = -2\log(\mathrm{L}(\hat{\theta}\,|\,y)) + 2K \,, \qquad (1)$$

where $\log(\mathrm{L}(\hat{\theta}|y))$ is the value of the log likelihood function at its maximum point for the vector of parameters designated by θ, given the data *y*, and K is the number of estimable parameters, including the intercept and the residual variance.[36] If the candidate models are fit by least squares regression and the outcomes are not transformed, the maximum likelihood estimate (MLE) of the residual variance can be calculated directly from the residual sum of squares (RSS/n) (Burnham and Anderson 2002).[37]

The AIC's of all models in the set of candidates can be rescaled to simplify the comparison and ranking process:

$$\Delta_i = \mathrm{AIC}_i - \min(\mathrm{AIC}) \,, \qquad (2)$$

where index *i* indicates the number of the model and min(AIC) is the smallest AIC value.

The relative values of Δ_i indicate the level of support for the given model. A rule of thumb is that models varying by only 1 or 2 from the best model have strong support; models with Δ_i's between 3 and 7 show less support and a value of 10 or more indicates little to no support (Burnham and Anderson 2002). However, these ground rules presume that all of the basic assumptions of linear regression are met.

The model weights reflect the probability that a given model is the best one among the set of candidate models. These weights are calculated as shown in equation (3),

$$w_i = \frac{\exp(-\frac{1}{2}\Delta_i)}{\sum_{i=1}^{R}\exp(-\frac{1}{2}\Delta_i)} \,, \qquad (3)$$

where R is the total number of models under consideration and *i* is the index for each model.

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[36] Maximum likelihood methods allow for the estimation of the parameters of interest, given a set of data and an assumed model. A brief introduction to maximum likely theory is provided in the Burham and Anderson text.

[37] The maximum likelihood estimator (MLE) is the value of the parameter for which the log likelihood function is at its maximum.

Burnham and Anderson also propose using the Akaike weights for model averaging in the event that two or more of the candidate models are in close contention, and model uncertainty can be incorporated into the sample variances of the estimators. This approach allows the researcher to reflect the uncertainty inherent in the identification of the candidate models and develop estimates based on a selected set of the candidates. Clearly, large differences in the values of the estimators of the top candidate models will result in wide variances.

There are some limitations to applying the information-theoretic approach. The candidate models must have the same number of observations and a similar structure. Models in which the dependent variable is transformed or that assume a lognormal distribution of errors (for example) cannot be compared with untransformed models (Burnham and Anderson, 2002).

6.1.2 Model Selection Process

The model selection process involves four steps: defining the candidate models, diagnostics to assess goodness of fit, running the models, comparing and evaluating the results. Each of these items is discussed in more detail below.

6.1.2.1 Defining the models

The first step is to establish a set of defensible candidate models appropriate to the immediate researchable question and the available data. Experience has shown that this step is the most difficult, requires a substantial time investment and can be the limiting factor in the overall success of the endeavor. The "garbage in, garbage out" rule applies to model selection as well as computers.

It may also make sense to divide the model selection process into multiple stages. The first stage may be a broad brush, with candidate models that are likely to represent wide variations in model fit (such as weather-dependent effects or various error structures), with the subsequent stages more of a fine tuning to compare combinations of variables that have a smaller impact on fit. The top ranking model in the first stage would then be used for all of the models compared in the second stage.

The advantage of the multi-stage approach is that there are fewer models to run and compare at each stage. For example, if there are twenty models in the first stage and ten in the second, conducting the model selection all together as one stage would require fitting 200 models, but using a two-stage approach would necessitate thirty models. However, this strategy only works if the top-ranked model in the first stage represents a substantial improvement in fit over the alternatives and the second-stage models would be unlikely to affect the results of the first phase.

6.1.2.2 Diagnostics

As is appropriate with any modeling project, the next step is to run the global model, i.e., the one with the most parameters, and calculate the diagnostic statistics to check for violations of assumptions. Common issues with billing data include heteroskedasticity and autocorrelation. It is also wise to check for multicollinearity among the variables. These diagnostics can help to identify serious issues with the data and allow the researcher to consider possible mitigating strategies, if needed. This process may lead to an expansion of the candidate models to incorporate a variety of error structures or other factors that may have been missed in the initial consideration of viable models.

6.1.2.3 Fitting the models

Once the list of candidate models has been completed, the researcher can begin to fit the models and compare the AIC for each model. Common statistics software packages often include the AIC in the output for the mixed models procedures. However, these values may be calculated for a different purpose and do not necessarily correctly count the number of parameters in the model. The number of parameters must include the intercept and the residual variance, in addition to the regression coefficients.[38]

6.1.2.4 Assessing the results

Once the AIC has been calculated for each model, the models can be ranked by AIC in descending order and the weights calculated for each model. These weights reflect the probability that a model minimizes the loss of information in relationship to the other candidate models, and can be used to determine whether the results from multiple models should be incorporated into the estimates through model averaging. If the top model is substantially better than any of the others or the estimates are very close for all of the top models, then model averaging is clearly unnecessary.

On the other hand, if two models are close contenders and the estimates vary between the models, then model averaging is a reasonable method to incorporate information from both of the top models. The same approach can be used to decide whether to incorporate model selection uncertainty into the confidence intervals calculated for the parameters. Wide variations among the estimates and relatively equivalent weighting could result in a substantial increase in the uncertainty associated with the parameter.

6.2 Fixed Effects Regression

Estimates for savings by end use were developed from fixed effects regression models, one for electric and one for gas. The type of modeling used in the analysis is often referred to as cross-sectional, time series (CSTS) analysis, in which the program-level data provided at

[38] Calculating the AIC from the output from ordinary or generalized least squares is discussed above in the theory section. The regression output typically uses n - (p+1) in the denominator, whereas n should be used for calculating the AIC. If the sample size is small enough to make a difference, this correction should be made.

the household level is the "cross-sectional" component and the monthly billing records are the "time series" data. These two sources of data are merged to create a CSTS data set. The discussion on regression covers a brief description of the general form, a list of the predictor variables, confidence intervals, model diagnostics and references.

6.2.1 General Form of the Model

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 the fixed effects model can be written as follows:

$$C_{it} = \alpha_i + \tau_t + \sum_{j=1}^{p} x_{ijt}\beta_j + \sum_{k=1}^{q} z_{ikt}\gamma_k + \varepsilon_{it}\,, \qquad \text{(XX)}$$

where

C_{it} is the monthly consumption for the household *i* in period *t*, expressed in monthly kWh per day,
α_i is the "customer-specific" intercept (or error) for household *i*, accounting for unexplained difference in use between households associated with the number of occupants, appliance holdings and lifestyle,
τ_t is the "time-specific" error for period *t*, reflecting the unexplained difference in use between time periods,
x_{ijt} are the predictor variables reflecting the installation of energy efficiency measure *j* for household *i* in period *t*,
β_j are the slope coefficients that quantify the average influence of modeled efficiency measure *j* on monthly consumption,
p is the total number of energy efficiency measures included in the model,
z_{it} are the predictor variables reflecting non-program related effect *k* (such as weather impacts) for household *i* in period *t,*
γ_k represents the slope coefficients that quantify the average influence of modeled non-program related effect *k* on monthly consumption,
k is the total number of non-program related effects included in the model, and
ε_{it} is the error term that accounts for the difference between the model estimate and actual consumption for household *i* in period *t.*

The "fixed-effects" aspect of the model arises from including the α_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.

The same approach is used to account for widespread influences causing variations in use over time. For example, the shorter days during the winter months may trigger longer lighting hours and consequently higher use of electricity. These time effects are captured by the variable τ_t which represents the variation in use over all homes from one period to the next.

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. 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.

6.2.1.1 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 2003) through the end of 2006. This period covers a years' worth of billing data before and after the PY 2005 installations. The kWh and therm data are in billing cycle frequency. The kWh and therm use are divided by the number of days in the billing cycle and then multiplied by 30.4 to ensure that all reads are consistently recorded in monthly kWh and therms.

6.2.1.2 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: Dummy variables marked the measures installed through the program by end use (lighting, refrigeration, cooling, hot water, and space heating)
- 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 number is below a temperature set point of 70, for example, there are no cooling degree-days that day. If the number is greater than 70, 70 is subtracted from it to find the number of cooling degree-days. For example, if the average temperature for a specific day is 80ºF, 80 minus 70 is 10 cooling degree-days. Set points of 70 and 75 were considered, and 70 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 base temperatures of 60, 62 and 65.
- Space heating equipment: The presence of working space heating equipment for homes that did not receive measures designed to reduce heating loads was modeled.
- Cooling equipment: As with space heating, the presence of central and room air conditioners in homes that did not receive cooling-related measures was explicitly include in the model.

Lists of the specific variables used in each model are given in Chapter 7, Section 7.6, Table 7-12 and Table 7-14.

6.2.1.3 Model Diagnostics

Combining CSTS data creates additional sources of variability. The underlying assumption behind pooling is that the cross-sectional units are homogenous. In real applications, this is rarely the case. Energy use in homes varies widely, as does the impact of the conservation treatments. Homes with electric space heat or unusually high use may well have different patterns of consumption than other homes.

For OLS, the assumption is that the error term is independent, has a constant variance and is normally distributed. In CSTS data sets, variation among the cross-sectional units may contribute to heteroskedasticity and the series of observations within each house may well be autocorrelated. Collinearity among the explanatory variables can also contribute to the uncertainty in the estimated intervention effects, sometimes resulting in estimators of the opposite sign.

These concerns highlight the importance of model diagnostics. The diagnostics were conducted on a subset of the eligible LIEE accounts, consisting of about 5,300 homes for both electric and gas. These homes were selected randomly in proportion to the total number of homes in each Title 24 weather zone. If the quota for a specific weather zone was less than 100 homes, the sample size was increased to 100.

Each of the three common basic OLS assumptions is discussed in more detail below with the diagnostic results for the LIEE data sets.

Heteroskedasticity

Unequal variances result from the wide fluctuations in energy use from one home to the next due to appliance holdings, occupancy and lifestyle, and are exacerbated by anomalous variations in consumption, either due to estimated reads or other unusual circumstances. The inclusion of the customer-specific intercepts does not completely mitigate the unexplained month-to-month variations.

Heteroskedasticity can be detected through plots of the residuals v fits and tested by modified Levene's test, the Goldfeld-Quandt test or other specification tests. An advantage of the modified Levene's test is that it is not sensitive to deviations from normality. To test the equality of variance at the household level, Levene's test can be carried out by calculating the absolute deviations and assessing whether the means are equal for all homes:

$$d_{ij} = | y_{ij} - \tilde{y}_i |^2 \qquad (17)$$

where $\tilde{y}_i$ is the median for house *i*,

i = 1, 2,…, N (number of homes) and

j = 1, 2,…, t (number of time periods for home i).

The test statistic is the usual ANOVA F statistic (Montgomery 2001:82).

The Goldfeld-Quandt test is another method that is particularly useful for assessing heteroskedasticity in CSTS data sets. This process requires calculating the variances of the residuals by cross-section (or time period) and ordering the cross-sectional units or time periods by nondecreasing variance of the residuals (Sayrs 1989:66-69). Separate regressions are then conducted for the top and bottom *k* cross-sectional units or time periods, and the ratio of the residual sum of squares is calculated. This statistic has an F-distribution with (N – R – 2K – 2)/2 , (N – R – 2K – 2)/2 degrees of freedom, where N is the total number of observations, R the number of central observations removed from the analysis and K is the total number of parameters to be estimated (Judge 1980: 148-149, Goldfeld and Quandt 1965).

Possible strategies for mitigating heteroskedasticity include weighted least squares regression and transforming the response variable.

Autocorrelation

Autocorrelation is commonly found in time series data, possibly resulting in biased variances. In this model, autocorrelation stems from the pattern of energy consumption during consecutive periods within each home, i.e., the amount of electricity used in one month is likely to be similar to consumption during the previous month. While the response variable in the fixed-effect model is the deviation from the expected use, this pattern will still hold to some extent.

While a positively autocorrelated data set should produce unbiased estimators, the variances of the coefficients are likely to be smaller than actually supported by the data. A number of strategies for mitigating first-order autocorrelation have been recommended, but even with these alternative strategies, errors are still likely to be understated in autocorrelated data sets, and care should be used in interpreting the results (Ostrom 1990:36). In a recent impact evaluation, bootstrapping was used to estimate standard errors for the regression coefficients, and the results suggest that actual errors may be 2.5 to 4 times higher than the OLS estimates (West Hill Energy and Computing 2005).

The Durbin-Watson test is commonly used to assess the presence of first-order autoregression in least squares regression. The calculation is given below:

$$d = \frac{\sum_{j=1}^{n-1} (u_{j+1} - u_j)}{\sum_{j=1}^{n} u_j^2} \quad . \qquad (18)$$

Values of the test statistic of approximately 2.0 indicate there is no autocorrelation, and a specified threshold (given the sample size and number of explanatory variables) is designated as the “uncertainty zone” where autocorrelation may exist. Values below the threshold lead to the conclusion that the data set exhibits statistically significant positive autocorrelation (Sayrs 1989, Durbin and Watson 1951).

The pooled Durbin-Watson is the value of this test statistic as calculated for each home and averaged over all cross-sectional units (homes). This variation on the Durbin-Watson statistic is more appropriate for the CSTS structure and reflects the presence of autocorrelation *on average* among all homes in the analysis. As with the regular Durbin-Watson statistic, a value close to 2.0 indicates that the data set does not show signs of an autoregressive structure (Sayrs 1989:19).

Collinearity

Collinearity tends to be an issue whenever many variables are incorporated into the analysis reflecting measures installed at the same time or when other effects have a high correlation with the measure installations. For example, light bulb and fixture replacements as well as the installation of low flow devices, tank wraps and pipe insulation are often installed at the time of the initial energy assessment.

Collinearity results in higher variances for both response and explanatory variables, and sometimes produces estimators having the opposite sign than would be expected. Four approaches to detecting collinearity were pursued:

(1) assessing the correlation between pairs of independent variables in the model,
(2) identifying nonsignificant t tests for individual beta parameters where the F test for overall model is significant,
(3) reviewing estimators with opposite signs from what is expected,
(4) calculating the variance inflation factor for each parameter of interest.

The variance inflation factor is calculated as follows:

$$VIF_i = \frac{1}{1 - R_i^2}, \qquad (19)$$

where R_i^2 is the multiple correlation coefficient of X_i regressed on the remaining explanatory variables and *i* is the index for the parameter to be estimated. A variance inflation factor of 1.0 indicates no correlation, whereas a high value suggests collinearity among two or more of the explanatory variables (Belsley, Kuh and Welsch, 1980:92-93). If collinearity is found, possible mitigations include bundling measures into groups or trying to obtain additional information (West Hill Energy 2005).

6.3 References

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7 Methods And Analysis

This chapter covers primarily the methods and analysis techniques used in the billing analysis. For the showerhead and on-site surveys, a brief description of the sampling plan is provided here, and more detail can be found in Appendices C and D, respectively. Since no separate report on the billing analysis was prepared, this chapter describes the models and application of those models to the actual data set in more detail.

In this chapter, we cover the procedures and approaches adopted in the course of the analysis due to the characteristics of the actual data. This chapter is organized into seven sections: sampling plan and weighting, developing trend lines, comparison group selection and use, simple pre/post modeling, model selection, specification of the regression model, and results of diagnostics.

7.1 Sampling Plan and Weights

7.1.1 Showerhead Survey

The sampling for the DHW flow devices used a two-stage cluster design. In the first stage, LIEE delivery contractors were selected to participate in the project. In the second stage, the target number of items was set for each agency to be collected within the specified time frame. The underlying principle is sampling proportional to size, with the goal that each showerhead installed in the expected time frame would have approximately the same probability of being selected for the survey. Contractors were directed to collect all showerheads and aerators from the start date until they reached their quota.

The final sample of the eleven contractors covered the three utilities and a large geographic spread. A total of 268 showerheads and 187 aerators were collected. One aerator was cracked, and thus could not be tested. In addition, six of the eleven contractors provided samples of the new, low flow showerheads they install through the LIEE program and two contractors sent in samples of their low flow aerators.

SCE was excluded from the sample due to the small volume of showerheads and aerators installed and the focus on obtaining more reliable information regarding gas savings. However, SCE has a substantial amount of overlapping territory with SoCalGas and PG&E and many of SCE’s contractors provide services to these other two utilities. Consequently, we expect that the results of the survey should be applicable to SCE as well.

The methodology used for calculating the mean flow rates, proportion of low flow devices replaced and standard errors is consistent with the two-stage cluster sampling approach, as described in Appendix C. The means and standard errors were weighted to reflect the relative contribution of each agency to the total number of showerheads replaced.

7.1.2 On-Site Survey

The sampling strategy is based on a three-stage approach, first stratifying by participation in the cooling and general surveys, and then drawing a two-stage cluster sample, with counties as the primary sampling unit and participants' homes as the secondary sampling unit, as shown below.

Stage	Sampling Unit	Stratification
1	General or Cooling	Survey Type
2	County	
3	Participant's Home	

The stratification relates to whether participants are to be selected for the general or cooling survey. LIEE Participants were eligible for the cooling survey if they received a cooling-related measure during program year 2005. All other participants were included in the sample frame for the general survey.

In the first stage of the cluster sample, counties were selected proportional to participation. Eight counties for the general survey (four for the cooling survey) were selected without replacement, with a quota of 40 completed surveys (20 for the cooling survey) in each county.

The only difference between the general and cooling survey is that the cooling survey was designed to gather additional information regarding the cooling systems and installed cooling measures. All of the other questions are the same. Consequently, the total achieved sample size of 399 surveys was used to develop the results from the general survey. Appropriate weighting factors were applied to account for the actual number of units in the population represented by each sampled unit. Overall, the distribution among the utilities in the sample was reasonably close to that of the total participants.

7.1.3 Billing Analysis

Data sets were 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 Section 4.4.

7.1.3.1 Simple Pre/Post

The comparison group is the only method for addressing external effects in the simple pre/post analysis. For this part of the analysis, we stratified both groups by utility and housing type, and developed case weights to reflect the population proportions for the 2005 participants. Finally, to balance the two groups in terms of pre-participation electricity and gas consumption, we calculated the quintiles of pre-participation consumption for the treatment group, and further weighted the comparison group to reflect those quintiles.

7.1.3.2 Regression Weighting

The regression analysis itself allows us to control for average usage levels by home and the variations due to seasonal and weather effects. These factors account for a large part of the variations across housing types and across utilities. Consequently, it was unnecessary to add a further weighting structure to the regression analysis to make the analysis group match to the population.

As a method of addressing heteroskedasticity, a weighted least squares model was tried and compared to the models with independent errors using the information-theoretic approach to model selection. The weights for the weighted least squares were calculated by regressing weather effects and installed measures on the billing use for each home and recording the root mean square by home. This value was then squared to obtain the variance for each home, and the weight is the reciprocal of the variance, scaled to the number of observations in the data set.

7.2 Developing Trend Lines

The central approach to modeling the savings attributable to the program is a pre/post installation billing analysis. The limitations of this approach are well known. One of the obvious weaknesses is that economic trends can occur over the three-year period of analysis, independent of the program, that can affect energy consumption. If these trends are not modeled they can bias the estimated savings severely. Two approaches to this problem were taken. One was to use a contemporaneous comparison group (described in detail later), and the other was to add some economic indicators as trend lines in the model.

The trend line approach was endorsed by the California Demand-Side Management Advisory Committee as a potentially effective way of controlling for the effects of history on energy consumption when using pre/post, time series modeling. These may be economic indicators, or a direct measure of energy consumption, depending on what historical events are most likely to be a danger to accurate estimation of program-related reductions in consumption. One suggestion made in the report was to take a random sample of customers over the program period and use the mean monthly consumption over the same period.[39]

In the specific case of the LIEE Program, however, a random sample of residential customers would not be appropriate, as any historical/economic impacts that have occurred over the evaluation period may affect low-income customers differently than others. All trend variables used in this evaluation should track the effects on low-income customers. The variable most obviously related to this group is the average energy consumption of the entire population of utility customers on the CARE rate. In addition, statewide

[39] Pacific Consulting Services. 1994. An Evaluation of statistical and engineering models for estimating gross energy impacts. Final Report for the California Demand-Side Management Advisory Committee: The Subcommittee on Modeling Standards for End-Use Consumption and Load Impact Models.

unemployment figures over the relevant time period were used, as well as regular, unleaded gasoline prices for the state.

The CARE rate customers' consumption was provided by the utilities, aggregated by billing cycle, i.e., the unit of analysis was the billing cycle. To be useful to savings analyses, this aggregate dataset had to be translated into daily average consumption for each day over the three-year analysis period. When in a daily form, the averages could then be re-aggregated to match participants' specific billing cycles.

The translation of aggregate billing cycle consumption to daily averages began by dividing the total consumption for each billing cycle by the number of days in the cycle to find an average daily consumption for the cycle. Then these average consumption results were averaged for each day in the three-year period, as appropriate to the day. An example will help to clarify this. September 1, 2004, for one utility, was part of 22 billing cycles. Thus, the average daily consumption for each of those 22 billing cycles was averaged to represent the average consumption for September 1 of that year. This process was completed for each day of the three-year period. Thus, each day represents the average of the averages of all billing cycles that include that day. This "daily consumption" dataset could then be merged onto the participant dataset, aggregating to each billing cycle for each participant.

The unemployment figures were taken from the Bureau of Labor Statistics' web site. The site provided monthly figures specific to California over the 2004 through 2006 time period. Both overall unemployment and number of initial claims were downloaded. These figures were provided by month, but were translated to daily numbers (the same number for each day of the month). This "daily" file could then be matched to the billing cycles of each participant.

The unleaded regular gasoline prices were taken from Department of Energy web site, in a weekly format. These weekly prices were translated into daily figures so that they could be re-aggregated into the billing cycles of the participants.

7.3 Comparison Group Selection and Use

The inclusion of the comparison group sparked a debate among our team. The core of the issue is that the comparison group introduces net effects into the model in a way that is difficult to quantify and the final results would be somewhere between net and gross impacts, making interpretation of the results difficult.

To place this discussion in context, it may be helpful to start with the definitions of gross and net savings. Gross savings are the actual reduction in energy use relating to the installation of a specific measure. Net savings are gross savings adjusted to account for the proportion of the savings that are directly related to the program, typically including estimates of free riders and spill over.

A confounding issue when conducting a billing analysis is that other external factors also influence energy use. A case in point is the LIEE 2002 Impact Evaluation, when the pre-installation period included the 2001 California Energy Crisis, thus both depressing pre-installation use and the savings estimated from the billing analysis.

A common assumption for low income programs, as used for the LIEE program, is that there is no free ridership and spill over, since low income customers are unlikely to make energy efficiency investments on their own. Thus, net and gross effects are equal. However, the on-site survey indicates that low income participants are purchasing CFLs and also replacing other appliances as needed. Although the new appliances may not be the most efficient models or meet the LIEE program standards, they are likely to use less energy than the original one, thus potentially confounding the program savings as estimated through a billing analysis.

The comparison group is the only method for addressing external effects in the simple pre/post analysis. However, the more sophisticated regression analyses allows us to control for average usage levels by home, the variations due to seasonal and weather effects and also to use other techniques to model external factors. For example, trend lines for known market influences can be incorporated as regression variables, as described in the previous section.

While the purpose of the comparison group is to try to control for external market effects, they may well also introduce some level of net effects into the model, and it is not possible to distinguish between the two. Our approach was to compare the results of the regression analysis using three data sets:

1. participants only
2. participants plus market trend lines
3. participants plus the comparison group

For the electric regression model, it turned out that the three scenarios produced very similar results, and consequently the simplest option, i.e., participants only, was used to estimate the program savings. In the gas model, the participants plus comparison group results in total savings about 14% lower than the participant only model, and the participants plus trend lines gives savings about 6% lower than the participant only model. Given the concerns about the possible inclusion of net effects by adding the comparison group and the fact that the model with the trend lines included was the top-ranked model in the model selection process, the final model was the participant plus trend lines (average CARE therm consumption and gas price).

7.4 Simple Pre/Post Modeling

For the participants in the pre/post assessment, we simply annualized consumption in the year immediately prior to the initial audit and compared it to annualized consumption in the 12-months immediately following the reported installation date of the last measure.[40] The change in the household usage for participants is calculated as follows:

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[40] We calculated annualized consumption as (total consumption)/(total days)*365 for the period between meter read dates that came the closest to a one-year period immediately preceding and following

$$\Delta U = U_{pre} - U_{post} \qquad (1)$$

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:

$$S = \Delta U_p - \Delta U_c \qquad (2)$$

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 2006 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. This analysis required assigning pseudo-treatment dates to each household in the comparison group that replicated, in aggregate, the distribution of treatment dates (and length of the period during which measures were installed) those of the 2005 participants. The process for selecting the control group was described in more detail in Section 7.3.

We also stratified both groups by utility and housing type, and developed case weights to reflect the population proportions for the 2005 participants. Finally, to balance the two groups in terms of pre-participation electricity and gas consumption, we calculated the quintiles of pre-participation consumption for the treatment group, and further weighted the comparison group to reflect those quintiles.

7.5 Model Selection

The model selection process was divided into three stages. The first stage involved the broader issues which tend to make a large difference in the AIC. (See Chapter 6 for a

participation in the program. We eliminated a small percentage of homes where the closest period that could be identified in either the pre- or post-treatment period was less than 330 days or more than 400 days.

description of AIC). The second stage is associated with the fine tuning of the measure variables, and the trend variables were added in the third and final stage. The modeling was done hierarchically, i.e., the best model from Stage 1 was used in all the models in Stage 2 and the best model from Stage 2 was used for Stage 3.

7.5.1 The Electric Model

The model selection process for the electric model is described in this section, and the gas model is explained in the following section. The electric model selection process was conducted using a subset of 10,022 of the 38,677 eligible accounts, unless otherwise noted.

7.5.1.1 Stage 1: Electric Model Structure

This stage entailed defining the overall model structure and possible strategies for modeling the non-program weather effects. The questions to be addressed in stage 1 are listed below:

- Does correcting for violations of the OLS have a substantial impact on the model fit?
- Does the benefit of including the monthly dummy variables overcome the drawbacks associated with increasing the number of variables in the model?
- What is the best strategy for modeling weather-dependent effects for homes that did not receive heating or cooling measures?

One of the outcomes of the model diagnostics (discussed in Section 7.7) is that the data set exhibits heteroskedasticity, that is the OLS assumption of the equal variances is not met in this data set. Weighted least squares is one method to address heteroskedasticity, and thus is included in the Stage 1 candidate models.

In CSTS models, heteroskedasticity is typically associated with some aspect of the model structure, in this case the unequal variances occur at the household level and is also associated with the consumption level within each home. Using the weighted least square method, each house is weighted according to the reciprocal of its variance, i.e., homes with higher variances are weighted less. The specifics of the weighted least squares method is explained above in Section 7.1.3.2, Regression Weighting.

The variance for each home was calculated by running a regression analysis on each home, using the measure variables and the presence of heating and cooling equipment. In a perfectly specified model, using a weighted least square method would be expected to produce the same estimators, but with smaller standard errors.

The diagnostics also indicate that autocorrelation may be an issue for this data set. Although both autocorrelation and heteroskedasticity are present in the model, it is not possible to mitigate both of these factors in the same model due to the high variability in the data set.

One approach to addressing autocorrelation is to use a mixed model based on maximum likelihood theory and apply a first-order autoregressive error structure. This modeling option was considered, but the wide house-to-house variances made it impossible to obtain estimates from the model.[41] However, it was possible to obtain estimates for a subset of homes that eliminated accounts with high and low pre-installation electric consumption levels.

Using a subset of 1,000 accounts, three models were run with the same set of variables and different model structures: independent errors, autoregressive first-order errors (to address autocorrelation) and weighted least squares (to address heteroskedasticity). Based on the information-theoretic approach to model selection described above in Chapter 6, the weighted least squares model was a huge improvement over both of the other two models, suggesting that addressing the heteroskedasticity has the more critical role in improving the model fit.

The second component is the time effects. The models were run with and without the monthly dummy variables that account for widespread differences in use over time.

The third part of this initial modeling was the weather-dependent effects. Four strategies were developed to estimate the heating and cooling use for homes with working electric space heating and/or air conditioning and no related LIEE measures:

1. Estimate heating or cooling use for each of four usage levels
2. Estimate heating or cooling use by utility weather station
3. Estimate heating or cooling use by CEC Title 24 weather zone
4. Estimate heating or cooling use for all homes with electric space heating or cooling and no LIEE measures of corresponding type

A total of eighteen models were run in Stage 1, as summarized in Table 7-1 below. The number of models is given in parenthesis in the category column and the total number of combinations comes to eighteen (2 x 4 x 2).

Table 7-1: Stage 1 Electric Model Options

Category	Options
Time (2)	Fixed No time effect
Weather-dependent Effects (4)	By four use levels By utility weather station By CEC Title 24 weather zone For all homes with ESH or AC and no LIEE measure
Within-house Error Structures (2)	Independent Weighted least squares
Total number of Models	16

The Stage 1 model selection process indicates that the monthly dummy variables contribute substantially to the model fit and the weather-dependent effects are best characterized by

41 The maximum likelihood estimators did not converge.

the use level rather than climate. The weighted least squares models showed a huge improvement in fit over the models with independent errors.

Table 7-2 compares the top five models from Stage 1. The column titled 'Δ_i' contains the difference between the AIC of the specified model and the AIC of the top model. Given that a difference of 10 shows strong support for the top model, one can see that the best fitting model represents a substantial improvement in fit over the second-ranked model.

Table 7-2: Stage 1 Top Five Electric Models

Rank	Weather-Dependent Effects	Time	Errors	Δ_i
1	By 4 use levels	In	WLS	-
2	By Weather Station	In	WLS	2,114.35
3	By Climate Zone	In	WLS	3,353.35
4	By 4 levels of use	Out	WLS	4,783.72
5	Estimate weather effects as average across all homes	In	WLS	4,934.64

7.5.1.2 Stage 2: Fine Tuning the Measure Variables in the Electric Model

For the envelope and air sealing measures, the modeling options were designed to look at three possibilities:

- the pre-installation use is the largest driver of savings,
- single family and multifamily housing best explain the differences in savings, and
- variations in heating slopes are mostly due to the different climate zones.

All heating and cooling measures were modeled by estimating the slope of the heating or cooling load separately for the pre- and post-installation periods and comparing them to estimated savings. The "measure" level variables sometimes modeled groups of the measures. Minor envelope and air sealing measures for electrically space heated homes were modeled as one variable.

One hypothesis tested for a number of the measures is whether the pre-installation use is the primary driver of the savings. For this purpose, accounts were divided into four levels of energy use. The first group included the 10% of accounts with the lowest usage, the second group were in the 10 to 50% bin, the third from 50% to 90% and the fourth were the 10% of accounts with the highest use.

The impacts of weather effects were also tested. Since there were few homes with electric space heating, the options were limited. The minor envelope/air sealing measures were the only ones with a sufficient number of accounts to divide into climate categories, and only the five CEC Title 24 climate zones could be used. Similarly, these smaller weatherization measures were the only ones with a substantial number of multifamily buildings and a sufficient number of accounts to try to estimate the savings by house type.

Another option explored in Stage 2 was whether the separate modeling of the evaporative cooler and room A/C replacements improved the model fit.

The options for modeling the variables are explained in Table 7-3.

Table 7-3: Stage 2 Variable Definitions

Variable	Options
Minor envelope/Air sealing (3)	By four use levels By single family v multifamily By CEC Title 24 climate zone (5)
Cooling (2)	Combined evap cooler & RAC by four use levels Separate evap cooler & RAC by four use levels
Refrigerators (2)	By four use levels Single dummy variable
Attic Insulation (2)	Dummy variable Scaled variable (area/(R-value$_{old}$ - R-value$_{new}$)
Total Number of Models	24

The Stage 2 process also indicated that the pre-installation use is a major driver of the savings levels, and is more important than distinctions between housing types and between climate zones for the envelope and air sealing measures. Scaling the attic insulation variable had the least impact on the model fit. (See Table 7-4 below.)

Table 7-4: Stage 2 Top Five Electric Models

Rank	Envelope/Air Sealing	Cooling Measures	Refrigerators	Attic Insulation	Δ_i
1	By 4 use levels	By 4 use levels	By 4 use levels	Dummy	-
2	By 4 use levels	By 4 use levels	By 4 use levels	Scaled	35.78
3	By 4 use levels	Evap/RAC by 4 use levels	By 4 use levels	Dummy	142.24
4	By 4 use levels	Evap/RAC by 4 use levels	By 4 use levels	Scaled	178.38
5	By SF/MF	By 4 use levels	By 4 use levels	Dummy	4,713.47

7.5.1.3 Stage 3: Adding the Trend Variables to the Electric Model

As discussed in Section 7.2, the modeling process included evaluating the effects of modeling external, non-program effects through the inclusion of trend variables. The four trend variables considered are as follows:

- Average Care kWh use
- Average Care billed amount ($)
- Gas prices
- Unemployment

Each of the trend lines was added separately and then the Care trend lines were added in combination with the gas prices and unemployment for a total of eight models. Adding the gas price alone actually resulted in a worse model fit and the estimator was not significant. The top two models are very close, indicating that both the Care kWh and billed amounts (which should be close) give similar results. (See Table 7-5).

Table 7-5: Stage 3 Top Five Electric Models

Rank	Trend Line	
1	Care Billed Amount & Unemployment	-
2	Care kWh & Unemployment	2.87
3	Care Billed Amount & Gas Price	85.70
4	Care Billed Amount	87.44
5	Avg Care kWh & Gas Price	156.32

As explained above, the actual program savings from the Phase II top model were very similar to the top-ranked Phase III model, and thus the participant-only (Phase II) model was selected for simplicity.

7.5.1.4 Final Modeling Options

Two other models were tested with the larger group that included all homes the billing analysis. These models were tested with the larger group due to concerns about small sample sizes associated with the specific estimators in the sample of accounts used for model selection.

The first option incorporated a variable to identify the contractors who also provided services under LIHEAP. This model was run using the top-ranked model from Phase II, but it did not rank as well as the Phase II model, suggesting that LIHEAP contractors are not introducing additional error (in the form of unknown installations) into the electric model.

The second option modeled cooling savings for homes with attic insulation. This model improved the model fit substantially, producing an AIC about 6,000 lower than the top Phase II model. Thus, this variable was kept in the final model.

7.5.2 The Gas Model

The model selection process for the gas model was similar, although the issues with the two models vary. The gas model selection process was conducted using a subset of 10,022 of the 38,670 eligible accounts, unless otherwise noted.

7.5.2.1 Stage 1: Gas Model Structure

This stage entailed defining the overall model structure and possible strategies for modeling the non-program weather effects. The questions to be addressed in stage 1 are virtually the same as those considered for the electric model:

- Does correcting for violations of the OLS have a substantial impact on the model fit?
- Does the inclusion of a time effects overcome the increase in the number of varaibles?
- What is the best strategy for modeling weather-dependent effects for homes that did not receive heating measures?

As with the electric model, diagnostics indicate that gas billing also exhibits heteroskedasticity and autocorrelation. The same process was used to evaluate the options as is described above under the electric model, with the same result, i.e., the weighted least squares had a substantially greater effect on the model fit and was included among the stage 1 options.

Monthly dummy variables to account for time effects are not a viable option in the gas model since the weather-dependent seasonal fluctuation in gas use coincide with the colder winter months and the vast majority of participants in the model have gas space heating. For this reason, the time effects were modeled with an annual dummy variable to account for widespread differences in use over time. The models were run with and without the annual dummy variables.

Most of the homes in the gas model had both gas space and water heating, providing a substantial sample size for homes with gas heating and allowing a wider choice of options for estimating heating impacts. The heating loads for homes with working gas space heating and no heating-related LIEE measures were modeled using four strategies:

1. Estimate heating or cooling use by the five CEC Title 24 climate zones and each of four usage levels
2. Estimate heating or cooling use by utility weather station
3. Estimate heating or cooling use by CEC Title 24 weather zone
4. Estimate heating or cooling use for all homes with gas space heating

The four use levels were defined in the same way as was done for the electric model, i.e, the first group included the 10% of accounts with the lowest usage, the second group were in the 10 to 50% bin, the third from 50% to 90% and the fourth were the 10% of accounts with the highest use.

A total of sixteen models were run in Stage 1, as summarized in Table 7-6 below. The number of models is given in parenthesis in the category column and the total number of combinations comes to sixteen (2 x 4 x 2).

Table 7-6: Stage 1 Gas Model Options

Category	Options
Time (2)	Fixed No time effect
Weather-dependent Effects (4)	By CEC climate zone (5) and four use levels By utility weather station By CEC Title 24 weather zone (16) For all homes with gas space heating and no LIEE heating measures
Within-house Error Structures (2)	Independent Weighted least squares
Total number of Models	16

As for the electric model, the Stage 1 results for the gas model show that the weighted least squares method represents a substantial improvement in fit (See Table 7-7). All of the eight WLS models ranked above the models assuming independent errors. The weather-dependent effects were best modeled by the climate zone and use level. The time effect is the only variable that is different between the first and second ranked model, and although the time effects have relatively little impact in comparison to the weather dependent effects and WLS, it still makes a major improvement to the model, with a difference in AIC of 730, substantially higher than the cut of off 10 recommended by Burnham and Anderson.

Table 7-7: Stage 1 Top Five Gas Models

Rank	Weather-Dependent Effects	Time	Errors	Δ_i
1	By 5 Climate Zones & use level	In	WLS	0
2	By 5 Climate Zones & use level	Out	WLS	730
3	By Weather Station	In	WLS	3,933
4	By Weather Station	Out	WLS	4,668
5	By 16 Weather Zones	In	WLS	6,672

7.5.2.2 Stage 2: Fine Tuning the Measure Variables

The gas model is substantially different from the electric model in that most homes received at least one measure designed to reduce space and/or water heating use, providing a large group of participants with these measures. Unfortunately, the large sample size does not overcome the issues with separating base and heating consumption, which is still a major obstacle that can affect our ability to tease out the savings from the individual measures.

As with the electric model, the Stage 1 modeling suggested that the level of pre-installation use is a primary indicator of heating usage. For the homes with gas space heating and no heating-related measures, combining the climate zone and the use level gave the best model fit. Thus, it seems reasonable to investigate whether the use level is also a driver of the savings. However, some caution is also in order. Unlike the electric model, virtually every participant has some space and/or water heating measure, and modeling every measure based on use level may introduce collinearity and result in unexpected outcomes.

The enhanced data collection strategies added for PY2005 included recording information on the number of occupants in the home, which could be useful for estimating savings from the package of DHW conservation measures. These measures were modeled using three approaches:

- estimate savings by the number of occupants per home
- estimate savings by the four pre-installation use levels
- estimate savings for all homes with DHW measures

Occupancy was divided into three categories: low (1 to 2 residents), moderate (3 to 4 residents) and high (more than four residents).

There were fewer homes with attic insulation, which suggested that simpler modeling strategies would be more appropriate for that group. For these homes, the attic insulation was modeled by the four use levels and by the five CEC climate zones.

In 2005, the utilities also began recording whether the space heating equipment was in working condition. In the model, all of the heating-related savings are only estimated for homes with working heating systems. However, for homes that had non-functional systems and these systems are then repaired or replaced, there would be additional heating load added to the system. The impact of modeling this increase in use was evaluated by incorporating this variable into the model selection process, with one set of models excluding this effect and another set explicitly modeling it by the five climate zones.

A combined variable was used to estimate the savings associated with minor envelope and/or air sealing measures, and likewise the entire package of DHW conservation measures was modeled as a single variable. Thus, a home with any one of the four DHW conservation measures (low flow showerheads and aerators, tank wrap and pipe insulation) would be marked as having the DHW conservation package.

All heating measures were modeled by estimating the slope of the heating load separately for the pre- and post-installation periods and comparing them to estimate savings. Given the prevalence of the minor envelope and air sealing measures and concerns about introducing collinearity into the model, these measures were estimated by the sixteen CEC Title 24 weather zones.

The options for modeling the variables are explained in Table 7-8 below.

Table 7-8: Stage 2 Variable Definitions for the Gas Model

Variable	Options
DHW Conservation Package (3)	By three occupancy levels By four use levels Single dummy variable
Attic Insulation (2)	By four use levels By five CEC climate zones
Heating System Not Working and Repaired or Replace (2)	By five CEC climate zones Omitted from model
Total Number of Models	12

The Stage 2 process also indicated that the pre-installation use is a major driver of the savings levels, and is more important than distinctions between housing types and between climate zones for attic insulation (See Table 7-9).

Table 7-9: Stage 2 Top Five Gas Models

Rank	Envelope/Air Sealing	Cooling Measures	Refrigerators	Attic Insulation	Δ_i
1	By 4 use levels	By 4 use levels	By 4 use levels	Dummy	-
2	By 4 use levels	By 4 use levels	By 4 use levels	Scaled	35.78
3	By 4 use levels	Evap/RAC by 4 use levels	By 4 use levels	Dummy	142.24
4	By 4 use levels	Evap/RAC by 4 use levels	By 4 use levels	Scaled	178.38
5	By SF/MF	By 4 use levels	By 4 use levels	Dummy	4,713.47

Stage 3: Adding the Trend Variables

The process of adding the trend variables to the electric model was repeated for the gas model, giving the results shown in Table 7-10. The top-ranked model by a fairly wide margin was the model that incorporated the average Care therms consumption with the gasoline price.

Table 7-10: Stage 3 Top Five Gas Models

Rank	Trend Line	Δ_i
1	Care Therms & Gasoline Price	-
2	Care Therms	395.28
3	Care Therms & Unemployment	395.81
4	Gasoline Price	860.05
5	Care Billed Amount	964.65

7.6 Specification of the Regression Model

The savings estimates were developed using two regression models: one for electric measures and one for gas. Customer intercepts are incorporated into both 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.

7.6.1 Fuel Types for Heating and the Presence of Cooling Equipment

In the 2002 LIEE Impact Evaluation, fuel types were missing for a significant proportion of the participants and there was no way to identify homes with cooling equipment. This 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.

The Team worked with the utilities to improve the data collection procedures, and the utilities provided the fuel types for most of the 2005 participants. In addition to the fuel types for space heating and the presence of cooling equipment, the utility data sets also indicated whether the equipment was in working condition. Since this information was incorporated into the on-site data collection procedures, we expect it to be quite reliable.

This enhanced data collection enabled us to identify correctly the homes with heating- and cooling-related savings in the electric and gas models, and to model the space heating and cooling loads for homes that did not receive measures associated with these end uses. The marker indicating whether the original heating or cooling equipment worked was critical for identifying the increased use for homes in which the non-functional equipment was replaced or repaired.

7.6.2 Common Variable Definitions

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 monthly kWh (daily kWh for the period multiplied by 30.4 days) or monthly therms.

To estimate measure savings, the measure variables are interacted 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 were multiplied by the average daily degree days for the participants with the measure to obtain the annual kWh savings. For the weather-dependent measures, two variables were added, one to estimate the heating or cooling slope during the pre-installation period and a second to estimate the slope during the post-installation period. The coefficients were then compared to estimate the savings for these measures.

The electric model includes monthly variables to account for the time effects. This approach allows us to account for the monthly variation in usage that is not related to the program or other known factors. In the gas model, a dummy variable for each year was incorporated into the model to pick up changes in use over time.

Only one heating-related measure was identified for each home. This approach avoids collinearity in the measure specifications. Attic insulation was assumed to be the measure with the largest potential impact, and therefore was identified as the primary heating measure. Heating system measures were second, and the smaller air sealing and minor envelope repair measures were marked only for homes without attic insulation and heating system repairs or replacements. Thus, if a home had attic insulation, this measure was the only heating-related savings captured for that home and any savings from air sealing or enveloped measures or heating system repairs would be included.

To avoid overstating savings, the savings from the regression model were estimated only for homes with working gas space heating systems and the single heating-related measure modeled, and the savings were averaged overall all homes that received the measure and had a working heating system. These are the values that were then applied to the program population to estimate total savings.

7.6.3 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 1993 through early 2007 by weather station, and these data were averaged and summed to obtain the heating and cooling degree days for each read period. The weather station associated with each participant's home was identified in either the program tracking data or the billing data (depending on the utility). The program and weather data were merged with the billing history for use in the regression model.

The coefficients for all variables interacted with cooling or heating degree days were 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.

For the cooling measures, 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.

7.6.4 Electric Model

This model was used to estimate the savings from efficient refrigerators, lighting, hot water conservation and cooling measures. The number of households included in the models are shown in Table 7-11.

Table 7-11: Electric Model Sample by Utility and Measures Installed

	# of Households use for Model Selection	Total # of Households in Final Sample
Total # of Accounts	10,173	39,825
Utility		
PG&E	5,513	21,556
SCE	3,417	13,374
SDG&E	1,243	4,895
Measures Installed		
Refrigeration	4,559	17,611
Lighting	9,826	38,397
Hot Water Conservation	458	1,674
Cooling	460	1,908
Attic insulation	27	89
Minor envelope/air sealing	96	400

Table 7-12 below gives the definitions of the all of the variables included in the final electric model. The coefficients for the listed variables associated with measures are highly significant except for the hot water conservation package. The detailed output from the regression analysis is provided in Appendix F.

Table 7-12: Variables in the Final Electric Model

Variable Name	Number of Variables	Interaction	Measure Estimated	Meaning
Ihtguse1 to ihtguse4	4	Has working electric space heat * monhdd * use level	None	Estimates the heating slope for homes with ESH who did not rece LIEE measures associated with space heating (monhdd = monthl heating degree days)
Iclguse1 to ihtguse4	4	Has working A/C * moncdd * use level	None	Estimates the cooling slope for homes with A/C who did not recei LIEE measures associated with cooling (moncdd = monthly cooling degree days)
Oltg	1	Ltg* dpost	Lighting	1 if any lighting measures was installed, 0 otherwise
nrefuse1 to nrefuse4	4	ref* dpost* use level	Refrigerator	1 if a refrigerator was installed in a homes in each of the four use 0 otherwise (nrefuse1 = homes in use level 1)
Ians	1	Ians* dpost* monhdd* working ESH	Attic Insulation	Estimates heating slope during the post installation periods for ho with attic insulation and ESH
Ianspre	1	Ians* (prepost=1) *monhdd* working ESH	Attic Insulation	Estimates heating slope during the post installation periods for ho with attic insulation and ESH
Iansclg	1	Ians*dpost*moncdd* working A/C	Attic Insulation	Estimates cooling slope during the post installation periods for ho with attic insulation and working A/C
Iansclgpre	1	Ians*(prepost=1) *moncdd* working A/C	Attic Insulation	Estimates cooling slope during the pre installation periods for hon with attic insulation and working A/C
Imhtguse1 to imhtguse4	4	(env or aslg)* working ESH * monhdd *dpost	Minor envelope/air sealing	Estimates heating slope during the post installation periods for ho with envelope and/or air sealing measures and ESH
Imhtgusepre1 to imhtgusepre4	4	(env or aslg)* working ESH * monhdd* (prepost=1)	Minor envelope/air sealing	Estimates heating slope during the pre installation periods for hon with envelope and/or air sealing measures and ESH
imclguse1 to imclguse4	4	clg*dpost* use level * working A/C	Evap cooler or A/C	Estimates cooling slope during the post installation periods for ho with cooling measures and working A/C

Variable Name	**Number of Variables**	**Interaction**	**Measure Estimated**	**Meaning**
imclgusepre1 to imclgusepre4	4	clg* (prepost=1)* use level * working A/C	Evap cooler or A/C	Estimates cooling slope during the pre installation periods for hon with cooling measures and working A/C
Odhw	1	Dhw*dpost* electric DHW	Hot water package	1 if any hot water measure was installed in a home with electric w heating, 0 otherwise

7.6.5 Gas Model

The gas and electric models are similar, relying on the same set of variables to the extent that it is appropriate. The number of households included in the models are shown in Table 7-13. Monthly dummy variables were not included in the gas model due to the natural seasonal fluctuations in gas usage. However, three dummy time variables for years 2004, 2005 and 2006 were added to account for fluctuations from year to year.

Attic insulation is modeled separately and minor envelope and air sealing measures are combined into one variable. Furnace replacement and heating system maintenance are also represented by a single variable.

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. In particular, the measures associated with space heating remained fairly stable but the DHW conservation package savings tended to be highly variable dependent upon the base temperature used for the heating degree days.

Table 7-13: Gas Model Sample by Utility and Measures Installed

	# of Households used for Model Selection	Total # of Households in Final Sample
Total # of Accounts	10,019	38,670
Utility		
PG&E	4,847	18,759
SoCalGas	4,382	16,854
SDG&E	790	30,057
Measures Installed		
Attic insulation	695	2,600
Minor envelope/air sealing	8,825	33,958
Hot Water Conservation	9780	37,696
Heating System Repair or Replacement	224	826

Table 7-14 describes the variables in the final gas model. All of the variables were highly significant.

Table 7-14: Variables in the Final Gas Model

Variable Name	Number of Variables	Interaction	Measure Estimated	Meaning
Ihtgr1use1 to Ihtgr5use4	20	Has working gas space heat * monhdd * use level * (no LIEE heating measure)	None	Estimates the heating slope for homes with GSH who did not receive LIEE measures associated with space heating; the first number in the variable name is the CEC climate zone, the second one is the use level
Ihsnowork	5	(Had a GSH repair or replacement) * monhdd * GSH not working	None	Estimates increase in post-installation use due to having a working heating system; estimated by CEC climate zone
Iansuse1 to ainsuse4	4	Ians*dpost* Use level * monhdd* working GSH	Attic Insulation	Estimates heating slope during the post installation periods for homes with attic insulation and GSH by use level
Iansusepre1 to iansusepre4	4	Ians* (prepost=1)* Use level*monhdd* working GSH	Attic Insulation	Estimates heating slope during the post installation periods for homes with attic insulation and GSH by use level
Imhtguse1 to imhtguse16	16	(env or aslg) * monhdd *dpost* working GSH *(weather zone)	Minor envelope/ air sealing	Estimates heating slope during the post installation periods for homes with envelope and/or air sealing measures and GSH by CEC weather zone
Imhtgusepre1 to imhtgusepre16	16	(env or aslg)* working GSH * monhdd* (prepost=1) * (weather zone)	Minor envelope/ air sealing	Estimates heating slope during the pre installation periods for homes with envelope and/or air sealing measures and GSH by CEC weather zone
Ihsrep1 to ihsrep5	5	(Hs repair or replace)*dpost* use level	Heating system repair or replace	Estimates heating slope during the post installation periods for homes with heating system repair or replacement and working GSH

Variable Name	**Number of Variables**	**Interaction**	**Measure Estimated**	**Meaning**
Ihsrep1 to ihsrep5	5	(Hs repair or replace)*dpost* use level	Heating system repair or replace	Estimates heating slope during the pre installation periods for homes with heating system repair or replacement and working GSH
Odhwocc1 to odhwocc3	3	Dhw*dpost* occupancy level * gas DHW	Hot water package	1 if any hot water measure was installed in a home with gas water heating, 0 otherwise; by occupancy level
Oliheap	1	LIHEAP contractor * dpost	None	Extra base savings from LIHEAP contractors; 1 if contractor also works for LIHEAP; 0 in the pre-period, 1 in the post period
Iliheapthg & iliheaphtgpre	2	Oliheap*monhdd*GSH works	None	Extra heating savings from LIHEAP Contractors; separate estimators for pre and post periodsT
Avgcarethm	1	None	None	Trend line with average CARE therms
Gas Price	1	None	None	Trend line with gas price

7.6.6 Housing Types

One of the requirements of the evaluation is to provide savings estimates by housing type. This is a highly complex issue with no obvious and straightforward approach. While the heating-related savings for air sealing and envelope measures were separated into housing types according to the difference in heating loads, as described below, there is some debate about whether the relationship of the heating loads among the housing types applies to the savings that can be achieved in each type of housing, since the actual savings are dependent on the characteristics of the housing stock as well as the pre-installation heating load.

For weather-dependent loads, the Team conducted a separate analysis on the pre-installation consumption to assess the difference in heating and cooling loads for single family, multifamily and mobile homes. These factors were then used to estimate the multifamily and mobile savings for the air sealing and envelope measures. For gas attic insulation, the savings were estimated at the four consumption levels, and this information was used to estimate the savings by house type. Heating system measures were rarely installed and break out by housing type reflects the differences among the climate zones more than the differences between housing types.

For non-weather dependent loads, the regression results for some measures allowed us to scale savings to housing type based on usage. The savings from the DHW conservation package were not estimated separately by housing type.

Ultimately, estimating savings by housing type is more art than science and likely to be based on assumptions that cannot be verified. The Team recommends that the LIEE utilities consider whether it is worthwhile to continue to spend substantial time and effort to parse out the savings by housing type.

The methods used in this report are discussed in greater detail below. The Team will review these methods before finalizing the report and consider whether the savings estimates by housing type can be improved.

7.6.6.1 Weather-Dependent Loads

We conducted a separate analysis of heating and cooling loads for program participants. The purpose of the analysis was provide the ability to extrapolate space conditioning savings estimates for single family homes (which tend to dominate the savings analyses) to multifamily and mobile home households in the program. This process will be reviewed before finalizing the report.

This first step was to analyze gas space heating loads and air conditioning loads (central and room) using pre-treatment consumption histories for program participants identified in the program tracking databases as having these end uses. For the air conditioning analyses, we eliminated households that were also listed as having electric space heat.

We used the correlation between consumption and degree-days to statistically estimate the magnitude of space conditioning loads and provide a basis for weather correction.[42] Specifically, the following linear relationship was assumed and fitted to each household in the analysis:

$$C = \alpha + \beta * DD\tau$$

Where,

C = consumption per day (therms/day or kWh/day)
α = non space-conditioning consumption per day
β = heating or cooling consumption per degree-day
$DD\tau$ = degree days per day at reference temperature τ

Our analysis allowed the degree-day reference temperature to vary individually among the households, since the appropriate degree-day reference temperature is based on individual characteristics such as thermostat set-point, internal gains and thermal integrity of the building.   We found the best-fit reference temperature for each household by evaluating the model fit across a wide range of reference temperatures and choosing the one with that best fit (ie. highest r^2) within a range of plausible reference temperatures.[43]

To translate the model results into weather normalized annual heating or cooling loads, we multiplied the fitted heating or cooling slope coefficient (β) for each household by long-term (1993-2005) average degree days at the best-fit reference temperature.

In cases where a household exhibited a *negative* correlation between consumption and degree-days across all plausible reference temperature, we set the heating or cooling consumption to zero. This was particularly an issue for air conditioning loads in some of the coastal climate zones, where upwards of 40 percent of households showed no positive correlation between electricity consumption and cooling degree days.

We conducted all of our analyses by housing type and climate zone where we had at least 30 usable households within a housing type category and climate zone. For housing types and climate zones with fewer than 30 cases, we imputed average loads based on the relationship between normal degree days and average loads for the climate zones and housing types with sufficient cases.

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[42] Degree days were based on weather data for the individual weather station assigned to the household in the utility tracking system. In all, about 50 weather stations were used in the analysis.

[43] This step required additional heuristics to deal with households that showed no clear best-fit reference temperature or had multiple local r^2 maxima: our general approach in these instances was more heavily weight the reference temperatures that were closest to the median for all households of the same building type and climate zone.

Table 7-15 provides some key results from the analysis. The vast majority of households with gas space heat had detectable loads from the analysis, with a statewide average of 200 therms/year for single family homes, 70 therms per year for households in multifamily buildings, and 260 therms/year for mobile homes.

One caveat with the space heat estimates is that the figures probably include some portion of water heating usage as well: water heating tends to be seasonally variable in a way that mimics space heating load, and the seasonally variable portion tends to be mis-identified as space heating in models such as those employed here. The relative magnitude of these errors would be greatest in climate zones and housing types with low space heating loads.

Across all climate zones, the data suggest that participating households in multifamily buildings have only about a third of the heating load of single-family houses and mobile homes use about one-third more energy than single-family homes. The former result is likely due to the lower exposed shell area (and relatively higher internal gains) for multifamily housing compared to single-family housing; the latter may be due to relatively less insulation in mobile homes.

For air conditioning, the analysis suggests that a significant minority of households in the coastal climate zones do not use their air conditioning enough for it to be detectable in monthly consumption histories. When these households are averaged in with households that do exhibit detectable air conditioning loads, single-family and mobile homes show a statewide average of 900 to 1,100 kWh annual air conditioning loads, with households in multifamily buildings using in the range 600 to 950 kWh per year. Air conditioning loads in the climate zones where air conditioning measures are allowed under the program (Zones 11-15) show significantly higher loads, especially for Zone 15.

Table 7-15: Annual Heating and Cooling Loads by Housing Type and Climate Zone

Climate Zone	Gas Space Heat			Central AC			Room AC		
	Single-family	Multi-family	Mobile Home	Single-family	Multi-family	Mobile Home	Single-family	Multi-family	Mobile Home
	Weather Normalized Annual Consumption (therms or kWh)[a]								
1	340	*140*	310	NA	NA	NA	*370*	NA	NA
2	280	110	320	200	190	280	210	190	290
3	200	90	300	130	*270*	*420*	110	*260*	*380*
4	230	80	200	390	*380*	*540*	390	*410*	*500*
5	140	60	*220*	NA	NA	NA	NA	NA	NA
6	*150*	60	*230*	*150*	360	*430*	*140*	330	*390*
7	110	40	*220*	370	140	*570*	350	140	NA
8	250	90	*220*	430	440	*510*	430	450	*480*
9	200	40	*230*	820	560	*770*	780	510	*740*
10	120	60	*250*	980	860	1200	1000	830	1200
11	280	120	350	1420	1030	1360	1380	1050	1310
12	260	110	290	1080	840	1310	1030	810	1280
13	180	100	210	1750	1450	1790	1660	1350	1630
14	*300*	50	*290*	1210	1260	*1650*	1170	1220	*1680*
15	90	20	*210*	5100	2810	*3530*	4810	2840	*3460*
16	530	*150*	*310*	*1200*	NA	*1370*	*1150*	NA	*1300*
State[b]	200	70	260	1150	950	1210	900	620	1160
	Percent of Households with No Detectable Load[c]								
1	1%		0%						
2	0%	2%	0%	40%	33%	39%	45%	38%	40%
3	2%	11%	4%	56%			61%		
4	2%	8%	5%	40%			38%		
5	2%	7%							
6		19%			28%			31%	
7	2%	11%		36%	50%		46%	55%	
8	0%	9%		33%	27%		35%	29%	
9	1%	13%		21%	17%		21%	22%	
10	1%	2%		11%	9%	9%	12%	11%	10%
11	0%	1%	0%	6%	8%	11%	7%	9%	10%
12	1%	4%	2%	16%	10%	5%	18%	12%	6%
13	1%	3%	1%	6%	4%	6%	6%	5%	7%
14		0%		10%	5%		12%	5%	
15	2%	9%		7%	0%		6%	0%	
16	0%								

[a]*Italics* indicate value imputed from other climate zones for the same housing type. "NA" indicates no 2005 participant households with the end use in the utility tracking data. Includes cases with zero load. Values are rounded to the nearest 10.
[b]Weighted by 2005 participant population.
[c]Reported only for housing types and climate zones with at least 30 cases.

Focusing on the climate zones where air conditioning measures are installed, on average households in multifamily buildings have annual cooling consumption that is 79 percent that of single-family homes, while mobile homes use 110 percent of what single-family homes use.[44]

7.6.6.2 Non-Weather Dependent Measures

For refrigerators, the savings are estimated by pre-installation consumption level, This information was used to scale the savings to the housing types. For example, multifamily homes tend to have more homes in the lower consumption categories, and thus a higher percentage of multifamily homes would have lower savings. The consumption levels are defined in Section 7.5.1.2.

For the DHW conservation package in the gas model, occupancy level was used to define the variables. The occupancy levels were defined as follows: low occupancy (level 1) included homes with one or two occupants, moderate occupant (level 2) homes with three to four occupants and high occupancy (level 3) homes with four or more occupants. Although the top-ranked model incorporated this method of modeling the DHW savings, the actual savings estimators were quite close, i.e., 7.4 therms for level 1 and 8.9 therms for the two higher occupancy levels. Consequently, there was no clear method to estimated these savings by housing stock. The Team will continue to consider options to address this issue in the final report.

7.7 Results of Diagnostics

The effects of heteroskedasticity, collinearity and autocorrelation were assessed as part of the model diagnostics. Model misspecification is also discussed.[45]

7.7.1 Heteroskedasticity

The Goldfeld-Quandt (GQ) test was conducted to test for heteroskedasticity (unequal variances). The GQ test was run assuming that the heteroskedascity occurred at the household level and was also associated with the magnitude of the pre-installation consumption. For the electric model, the GQ statistic was over 6, which is substantially above the F-value of 1.0 required to conclude that the data set does not exhibit heteroskedasticity at the 5% confidence level. For the gas model, the GQ statistic was about 5.

To try to mitigate the heteroskedascity, weighted least squares (WLS) models were fitted and included among the candidate models. For the gas model, the GQ statistic for the WLS model was close to one, indicating that this strategy was quite effective. A similar result was found in the gas model, with the GQ statistic dropping from 6.7 to 0.96, indicating that the WLS data set does not appear to exhibit heteroskedascity at the 95% confidence level.

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[44] These figures blend central and room air conditioning: roughly three of four participants households with air conditioning have the former and one in four have the latter.

[45] Belsley, Kuh, and Welsch, *Regression Diagnostics*, is an excellent source of detailed information on diagnosing the violations of assumptions that commonly occur in regressions analyses.

These results tend to lead to the conclusion that both data sets exhibit signs of heteroskedasticity and the WLS model mitigates this violation of assumptions. However, heteroskedasticity is difficult to assess if the model is mispecified, which is clearly a possibility with these data sets, as discussed below.

7.7.2 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. The regression variables were defined to try to minimize collinearity, particularly among the heating-related measures, as explained in Section 7.6.2. To assess whether collinearity was an issue with the models, the correlations and variable inflation factors were reviewed for the gas and electric models and estimators were reviewed to see if they exhibited the expected sign.

The effects of collinearity were most problematic in electric model. There is a moderate correlation (.55) for homes with both electric DHW and electric space heating, and also a noticeable correlation (.52) between homes that received the electric DHW package and those homes with electric space heating that received air sealing and envelope measures.

These results explain the issues in estimating savings for homes with electric water heating who received DHW conservation measures and also those homes with air sealing or envelope measures and electric space heat. Almost all of the homes with EDHW 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. The sign on the estimators for the air sealing and envelope measures are the opposite of what one expect, suggesting that these measures cause higher electric usage. This result is another common sign of collinearity.

The electric model does not seem to indicate any other sources of significant collinearity. The variable inflation factors (VIF's) for most of the variables are between one and three. The VIF for lighting is 6.46, which is not surprising given that lighting is installed in almost every home.

For the gas model, there were no strong correlations between the measures, and the variable inflation factors for most of the variables were close to one, with the highest value of 2.68 for one of the time variables, indicating that there is little or no collinearity among the explanatory variables.

7.7.3 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 pooled Durbin-Watson test for autocorrelation results in a score of 0.92 for the electric model and 0.90 for the gas model. These values are substantially below the desired value of 2.0, indicating positive autocorrelation exists in the data sets.

The presence of autocorrelation would not be expected to have an impact on the values of the coefficients, i.e., they remain unbiased, although it tends to reduce the magnitude of the standard errors. Efforts to address autocorrelation are discussed under Stage 1 model selection for the electric model in Section 7.5.1.1.

7.7.4 Model Misspecification

Model misspecification occurs when critical variables are omitted from the model or irrelevant variables are included. However, there is no simple test for model misspecification.

In this case, we only have information about the measures installed and changes in the weather to explain the variations in energy in energy use over time. Energy consumption is highly complex and even constructing a list of all the relevant factors that could affect changes in use is a daunting task. Given our lack of data regarding non-program related changes in the homes over time, we are in the position of assuming that the large sample size will even out many of the typical changes that occur in the residential sector. Thus, it is likely that one or more relevant variables could be missing from our models.

8 Results

This section covers the results from all aspects of the study, including the showerhead survey, on-site survey and billing analysis. The overview gives the per household estimates of savings and discusses the components of the study. The results of the simple pre-post billing analysis are then presented, leading into a discussion of the electric and gas regression models. The following two sections cover a brief discussion of the results from the showerhead and on-site surveys. The next section describes how all of these components were integrated to develop the measure level savings. In addition, our team has conducted an analysis of potential electric savings associated with reduced water pumping and treatment costs from the installation of low flow showerheads, which was summarized and inserted before the final section in this chapter. The last section presents the program savings by fuel type, utility, measure and housing type.

8.1 Overview

A combination of the billing analysis, showerhead/aerator survey results, the on site surveys and external sources were used to develop estimates of actual program savings. For each measure, the results of the regression analysis were compared to estimates from previous evaluations, external studies, and other data collected through the showerhead and on-site surveys in an effort to triangulate on estimates of energy impacts. The information-theoretic model selection process provided an objective basis for selecting among the candidate models and avoid results-based analysis. In aggregate, this process allowed us to place the results in context, identify potential biases in the estimators, and develop the most defensible estimate of savings for each measure.

Table 8-1 shows the annual estimated household savings for the 2000, 2001, 2002 and 2005 evaluations, along with the annual kWh consumption for the group of 2005 program participants used in the regression models, during the pre-installation period.

Electric savings increase steadily from 175 kWh per year in PY2000 to 421 kWh in PY2005. The current savings estimate represents a decrease of approximately 8% in electric consumption on average. The PY2005 electric savings are about 15% higher than the savings found in the PY2002 evaluation, with the largest increase in SCE's service territory.

The gas savings are more variable from one year to the next. The average household savings for the statewide program are 20 therms per year, or 5% of gas consumption on average. The PY2002 evaluation showed a dramatic drop in savings, most likely due to the effects of the 2001 California Energy Crisis. The PY2005 household savings are more in line with the results of the 2000 and 2001 LIEE impact evaluations.

Table 8-1: Comparison of Household Savings, PY2000 to PY2005

	Average Annual Energy Consumption[46]	PY2005 Evaluation	PY 2002 Evaluation	PY 2001 Evaluation	PY 2000 Evaluation
Electric Savings (kWh)					
Combined Utilities[47]	5,431	421	366	213	175
PG&E	5,778	438	399	236	240
SCE	5,306	421	286	203	153
SDG&E	4,240	348	370	215	89
Gas Savings (Therms)					
Combined Utilities	421	20	8	18	24
PG&E	459	20	9	18	28
SDG&E	397	14	4	13	13
SoCalGas	323	20	8	20	26

Total program savings by utility are summarized in Table 8-2 below.

Table 8-2: PY 2005 Total Program Savings

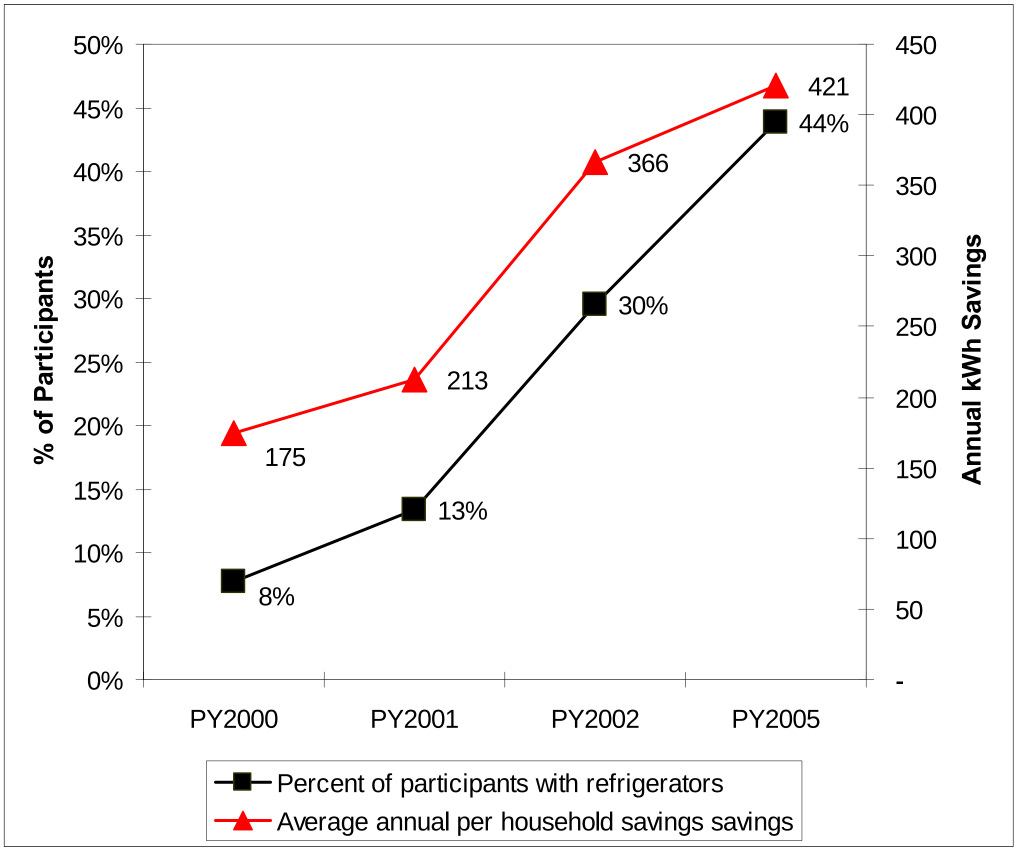
	# of Participants	Annual MWh	Annual Therms
PG&E	61,519	24,951	1,117,387
SCE	41,397	17,438	
SDG&E	13,737	4,717	156,387
SoCalGas	41,535		843,468
Totals	158,188	47,106	2,117,242

As was shown in the PY2002 impact evaluation, refrigerator installations are a major driver of the electric savings. The steady increase in household savings is matched by a higher penetration of energy efficient refrigerators. SCE had the highest penetration of efficient refrigerators in PY2005 with 48% of the LIEE household receiving one, following by PG&E with 42% penetration and SDG&E with 37%. Overall, about 44% of LIEE households received a new refrigerator. This trend of increasing savings and penetration of refrigerators is illustrated in Figure 8-1 below.

[46] This column reflects the average annualized kWh consumption for 2005 participants who were included in the account sample.

[47] Combined utility average consumption were calculated from the 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.

Figure 8-1: Household Electric Saving and Penetration of Efficient Refrigerators



It is interesting to note that SoCalGas's per household savings of 20 therms is the equivalent of PG&E's, although the climate is milder in SoCalGas's territory. This result is largely due to the higher penetration of measures in SoCalGas's program. Almost all of the SoCalGas participants (96%) received both weatherization measures (air sealing and minor envelope repair) and DHW conservation devices, whereas about 70% of PG&E's gas participants received both of these sets of measures. SDG&E has the mildest heating climate and also a lower penetration of both weatherization and DHW conservation measures among its gas participants (about 68%).

One difference between the PY2002 and the PY2005 reports is that we have collapsed a number of the measures into single categories for the PY2005. In this manner, we are representing savings that can be more reliably estimated through the regression models, rather than parsing out savings to a degree that cannot be supported by the billing data. In particular, the all of the air sealing measures (such as caulking and weatherstripping) and minor envelope repairs are included as one variable and only the combined savings are estimated. As we have discussed with the SAT committee, these measures only achieve savings in aggregate, and savings for individual measures are meaningless.[48] The savings from the DHW conservation measures is also estimated as a package, rather than

[48] The 2005 DEER database does not provide separate savings for caulking and weatherstripping, but rather provides savings for a specific reduction in infiltration rate.

attempting to estimate savings separately for each component. This approach has no effect on the total program savings and provides more reasonable and defensible savings estimates.

8.2 Simple Pre/Post Estimates of Savings

For electricity, the LIEE participants showed an average reduction in usage of 223 kWh/year, while the comparison group showed a comparable *increase* in consumption. Adjusting for this increase in consumption leads to an estimated average savings from the program of 446 ± 30 kWh/year, or 8.5 ± 0.6 percent of average pre-participation consumption.

Some of the observed increase in the comparison group is likely due to differences in the weather: statewide, there were about 16 percent more cooling degrees (base 70F) in the post-treatment period than in the pre-treatment period.

In contrast to the results for electricity use, the pre/post analysis for natural gas shows no statistically significant adjusted savings. The observed savings for the treatment group (17 therms on average overall) are closely matched by a similar reduction in gas consumption in the comparison group. Conducting a month-by-month pre/post comparison suggests that there are savings during the summer months that are negated by increased use during the winter months, suggesting the possibility that weather effects are confounding the model.

When reviewing these results, it is important to consider the limitations of this method. The simple pre/post analysis is often just a first step to gain a better understanding of the data. The easy-to-understand, simplistic nature of the approach is counterbalanced by the failure to account for a variety of key factors, such as weather.

An important component of the simple pre/post analysis is the comparison group, which is used to assess the impacts of non-program factors such as large social, economic and political factors. In this case, the comparison group was selected from 2006 participants, using their billing records during the period prior to program participation. The approach was selected on the assumption that 2006 participants would be be similar to 2005 participants.

While the comparison group is intended to correct for non-program influences on energy consumption, the underlying assumption is that the comparison group is perfectly matched to the PY2005 participants and does not introduce any undesirable effects into the model. Given the limited data available, it is not possible to determine the validity of this assumption. It is entirely possible at least some of the LIEE participants chose to enter the program due to energy-related problems they are experiencing in their homes, and thus there may be more volatility in their billing records during the pre-participation period. As discussed in Section 7.3, the comparison group could also introduce unmeasurable net effects into the analysis.

The participant regression analysis allows for sophisticated statistical controls for a variety of factors, and one would generally expect the results to be more reliable, although adding the comparison group may introduce the same factors into the regression analysis as mentioned above. However, the simple pre/post results of no savings for the gas model was an indicator of the issues that arose with the gas billing data, as discussed in the regression section.

8.3 Regression Results from the Electric Model

Table 8-3 shows the results from electric regression model. From the model selection process described in Chapter 7, Section 7.5, the top-ranked model had a number of estimators that were broken out by energy use level, thus accounting for the likelihood that homes with higher use may also have higher savings.[49] Reliable estimates of savings were found for lighting, cooling measures, and refrigerators. The estimators for the electric DHW package and minor envelope and air sealing measures in electrically space heated (ESH) homes do not appear to be reliable, as discussed further below. More details on the modeling are provided in Chapter 7, Section 7.6.

Table 8-3: Results from the Electric Regression Model

End Use/Measure	# of Homes	kWh Savings per Home	Standard Error	90% Confidence Limits	
				Lower Bound	Upper Bound
Lighting	8,397	57	2.91	52	61
Combined Cooling Measures					
Use level 1	35	(3)	12.95	(25)	18
Use level 2	414	11	8.74	(4)	25
Use level 3	1,045	123	9.80	107	139
Use level 4	401	432	29.80	383	481
Envelope/Air Sealing					
Use level 1	406	(34)	4.94	(42)	(26)
Use level 2	835	(97)	7.65	(110)	(84)
Use level 3	854	(112)	14.29	(136)	(89)
Use level 4	545	(65)	33.75	(121)	(10)
Attic Insulation – heating savings	86	252	44.81	179	326
Attic Insulation - cooling savings	388	22	11.35	3	40
DHW Package	1,609	45	7.15	33	57
Refrigerators					
Use level 1	1,565	276	2.89	271	280
Use level 2	6,984	642	2.95	637	647
Use level 3	7,165	875	4.96	867	883
Use level 4	1,748	1,198	20.80	1,164	1,232
Total # of Homes	39,825				

[49] As described in Chapter 7, the use levels are not evenly distributed. Rather, the lowest level account for the 10% of homes with the lowest use, the highest level for the top 10% of homes, and the remainder divided equally into two groups.

In Table 8-4 below, the regression results are combined to estimate the savings for the measures that clearly show a decrease in use. The average savings per home came to 397 kWh per year for the accounts included in this analysis.

Table 8-4: Measure Savings from the Electric Regression Model

					90% Confidence Interval	
	# of Homes	# of Items	kWh Savings per Home	kWh Savings per Item	Lower Limit	Upper Limit
Lighting	38,397	194,619	57	11	6	16
Refrigerators	17,462	17,654	760	760	755	766
Attic Insulation –heating	86	86	252	252	179	326
Attic Insulation –cooling	388	388	22	22	3	40
Cooling measures	1,895	1,927	162	162	140	184
DHW Package	1,609	1,609	45	45	33	57
Total Homes in Analysis	39,825					

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

- precision and sampling error
- estimating refrigerator savings by energy use level
- savings from electric water and space heating measures
- overall reliability of the results

In the next section, we will review all of the available information by end use and discuss the derivation of the final savings for each measure. Following this discussion, the tables of program savings for each utility by fuel type are presented.

8.3.1 Precision

The confidence intervals provide some indication of the variability in the group of participants used in the regression model. However, using a pooled, cross-sectional, time-series (CSTS) model tends to overstate precision since the actual observational unit is the home, but the model treats every billing record as an observation, thus substantially increasing the total number of observations used to calculate the standard errors that form the basis of the confidence intervals.

There are common violations of assumptions in a pooled CSTS model that can affect the variability in the estimates: heteroskedasticity (unequal variances) and autocorrelation. These two factors have opposite effects, in that heteroskedasticity tends to add variability and autocorrelation reduce it. Thus, a heteroskedastic data set will provide estimators with higher standard errors and an autocorrelated data set will produce results with lower standard errors.

In this analysis, the heteroskedasticity was mitigated through weighted least squares, but it was not possible to take equivalent steps to address the autocorrelation in the same model. In combination with the general propensity of the CSTS to understate variability, one can conclude that the standard errors from the regression analysis are likely to show less variability than is actually the case.

8.3.2 Estimating Refrigerator Savings by Use Level

A number of different methods for estimating the end-use level savings were pursued and compared through the model selection process described in Chapter 7, Section 7.5. Of these options, estimating the savings by energy use level was found to produce the best model fit. Accordingly, the output from the regression model includes refrigeration and cooling savings by energy use level.

As described in Chapter 7, Section 7.5.1.2, the energy use levels are based on pre-installation consumption and are set at levels to allow the savings from very large and very small users to be estimated separately. The lowest energy use level (level 1) reflects the 10% of homes with the lowest use, and level 4 is the highest 10% of users. The two middle levels represent the remainder of the participants in the analysis, divided into two groups at median energy use.

This method of estimating savings has another aspect that is valuable for this project. The utilities have requested estimates by house type, which led us to develop a method for distributing heating and cooling savings to house types as explained in Chapter 7, Section 7.6.6. However, there is little concrete information on the relative savings for refrigerators in the various types of housing stock.

Given that the refrigerator savings are already broken out by use level, it is possible to determine the number of homes in each use level by housing type and adjust savings accordingly. Since pre-installation use is a predictor of potential savings, this method is a reasonable approach and allows for the estimation of refrigerator savings by housing type.

8.3.3 Electric DHW package and Minor Weatherization Measures

The regression results indicate that indicates that LIEE participants with electric space heating (ESH) and minor envelope and air sealing measures used proportionally more electricity to heat their homes as the temperatures dropped. This result is unexpected and not consistent with our knowledge of heat loss in residential homes. In addition, the savings from the electric DHW package of measures are much smaller than would be expected.

These issues came up in the 2002 LIEE Impact Evaluation and have also arisen in other jurisdictions. For example, a recent impact evaluation for a low income program in Ohio was based on a billing analysis and was unable to estimate savings for the EDHW package.[50] Although the utilities improved the data collection for 2005 making it possible to identify the homes with electric water and space heating, it is apparent that this enhancement was not sufficient to overcome the range of other issues associated with these measures. The showerhead and on-site surveys provided some insights into the reasons for this outcome, as discussed below.

The DHW package and envelope/air sealing measures are likely to have small savings in relationship to the total household use, and are also likely to be highly variable from one home to the next due to the number of occupants and use of the heating equipment, making it difficult to estimate these savings from the regression model. The showerhead survey indicated that many homes already have low flow showerheads, which is the most commonly-installed item in the DHW package, suggesting that savings will only be found in a small subset of homes and it is impossible to identify those homes from the available information. A finding from the on-site survey was that many LIEE participants do not use their heating systems, and participants with ESH measures might be particularly frugal given the high cost of electric space heat.

In addition, the mild heating climate in many parts of California makes it difficult to separate base and heating use. The heating degree variable in the regression analysis is calculated from a base temperature of 65ºF, although the set point temperature is likely to vary from one house to the next.[51] A review of the weather data shows that half or more of the average annual heating degree days in some areas occur when the average daily temperature is between 60 and 65ºF. Within the band of temperatures, it is highly likely that heating system use is sporadic and will not be directly linear with the heating degree days, as is assumed in the regression model.

A third potential confounding factor is that homes with electric water heating often have electric space heating and/or refrigerant-based cooling systems, which introduces noise and collinearity into the model. Of the participants in the regression analysis with EDHW measures, over 75% also have electric space heat and about 90% have either electric space heat or a working refrigerant-based A/C system. Of the homes with ESH and measures targeted at reducing the space heating load, 70% have electric DHW or a refrigerant-based A/C system. An example of the effects of collinearity is that removing the variables for the envelope and air sealing measures (which currently shows up as an increase in use) lowers the savings for the DHW package substantially but has little to no effect on the other variables in the model.

Another possibility among this population is that participants may "take back" some of their energy savings in the form of greater comfort and may choose to keep their homes warmer or take longer showers.

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[50] Blasnik, Michael. 2004. Ohio Electric Partnership program impact evaluation, final report prepared for the Ohio Office of Energy Efficiency.
[51] The set point temperature is the outside temperature at which the heating system turns on.

8.3.4 Overall Reliability

Bias is a source of concern in any impact analysis. Many sources of error, such as measurement error, are not reflected in the "sampling" error, but may have a greater influence on billing results and lead to biased estimators. Since there is no way to measure the effects of these other sources of error, we verified our model results internally and also compared them to other estimates as a reality check.

For internal validation, we conducted diagnostics as discussed in Chapters 6 and 7, and also compared the results of the final model using weighted least squares to the same model without the weighting for the measures where savings were found. Given the range of issues that affect the change in energy use and the limited data available for the billing analysis, there are certain to be some key variables missing from the model and thus the model is likely to be misspecified to some degree. Such misspecification may lead to differences between the estimators from the weighted least squares and unweighted models, and a comparison of the estimators is useful to assess whether one of the estimators could be biased.

While there was a fair amount of variation among specific estimators, the actual savings for lighting, cooling measures, and heating and cooling savings from attic insulation were reasonably stable for most of the end uses or measures and the savings generally fell with the 90% confidence intervals of each other.[52] There was no consistent direction of the difference, i.e., the weighted least squares estimators were not consistently lower or higher than the unweighted estimators.

There were two measures with greater variation, i.e., refrigerators, and the electric DHW package. The refrigerator savings were approximately 15% higher in the weighted least square model, although both estimators are within a reasonable range and match up well with the results of previous evaluations.

The issues with the DHW package are likely to be related to the collinearity issues discussed above. The savings from the DHW package went from a modest 45 to virtually nothing (8 kWh). These results suggest that the savings from the DHW package cannot be reliably estimated from the model and we have employed alternative strategies for estimating these savings, as discussed in Section 8.7.2 below.

8.4 Regression Results from the Gas Model

Table 8-5 shows the results from gas regression model. As with the electric model, the information-theoretic approach to model selection was also used for the gas model. In this case, the top-ranked model indicated both energy use level and climate zones were critical factors in modeling the variables. All of the top models used the weighted least squares method to mitigate heteroskedasticty.

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[52] For this analysis, heating savings from attic insulation were estimated only in homes without electric DHW. The weighted least squares and unweighted estimators were fairly close and also matched up to the savings estimate for the final model.

Table 8-5: Results from the Gas Regression Model

Measure		# of Homes	Therms Saved per Home	Standard Error	Lower Limit	Upper Limit
Envelope/Air Sealing						
Weather Zone	1	355	27.1	4.1	20.4	33.9
Weather Zone	2	943	12.3	1.1	10.6	14.1
Weather Zone	3	4,621	8.5	0.5	7.8	9.3
Weather Zone	4	1,564	12.9	0.9	11.4	14.4
Weather Zone	5	292	15.3	2.0	12.1	18.6
Weather Zone	6	357	1.1	0.9	-0.4	2.7
Weather Zone	7	2,232	5.8	0.4	5.1	6.5
Weather Zone	8	3,242	3.5	0.4	2.9	4.1
Weather Zone	9	4,643	0.6	0.3	0.1	1.0
Weather Zone	10	2,477	14.1	0.7	12.9	15.3
Weather Zone	11	1,186	11.0	1.1	9.2	12.8
Weather Zone	12	2,427	19.8	0.7	18.7	20.9
Weather Zone	13	3,413	18.9	0.6	18.0	19.9
Weather Zone	14	412	8.7	1.5	6.2	11.2
Weather Zone	15	399	-0.8	0.6	-1.8	0.2
Weather Zone	16	650	12.0	1.3	9.9	14.1
Attic Insulation						
Use level 1	1	66	-2.5	1.2	-4.5	-0.4
Use level 2	2	609	19.3	1.5	16.8	21.8
Use level 3	3	1,193	59.2	1.9	56.1	62.4
Use level 4	4	435	140.1	5.4	131.3	149.0
Heating System Replace/Repair						
Climate zone	1	136	14.0	4.7	6.3	21.8
Climate zone	2	803	4.1	1.5	1.6	6.5
Climate zone	3	810	10.1	1.7	7.3	12.9
Climate zone	4	17	9.2	17.9	-20.1	38.6
Climate zone	5	47	6.1	5.1	-2.3	14.5
DHW Package						
Occupancy Level	1	16,159	7.4	0.2	7.1	7.7
Occupancy Level	2	10,557	8.9	0.2	8.5	9.2
Occupancy Level	3	10,147	8.9	0.3	8.5	9.3

The savings from the regression model are aggregated by measure in Table 8-6. The average savings per home are approximately 19.1 therms per year for the accounts in this analysis.

Table 8-6: Measure Savings from the Gas Regression Model

	# of Homes	Savings per Home (Therms/yr)	90% Confidence Interval	
			Lower Limit	Upper Limit
Air sealing/envelope	29,213	9.7	8.6	10.9
Attic Insulation	2,303	62.2	59.6	64.7
Heating System Repair/Replace	1,813	7.6	5.9	9.3
DHW Package	36,863	8.2	8.0	8.4
DHW Replacement	675	11.7	9.8	13.5
Total Homes in Analysis	38,670			

The gas model presented some major challenges. Separating base and heating use is difficult, particularly in the mild climate zones where half or more of the heating degree days occur when the temperature is between 60 and 65ºF. Changing the base temperature for the heating degree days had a substantial effect on the program savings. The differences in the estimators from the unweighted model to the weighted least squares model were also larger than would be expected. In contrast, changing the specifications of the variables generally had little effect on the value of the estimators.

The model selection process was conducted using the Akaike criterion without knowledge of specific parameters. After the final model had been chosen, various steps were taken to verify the savings and ensure that the resulting estimators fell within reasonable bounds, which was found to be the case. Each of the modeling issues is discussed in more detail below. The development of the actual per-measure savings is further explored in Section 8.7, Integration of Results.

8.4.1 Base HDD Temperature

The model was run separately using base HDD temperatures of 60 and 65ºF. At the higher temperature, less of the use was associated with the heating measures and more was associated with the base use, resulting in higher DHW savings and lower savings from heat-related measures. While information-theoretic model selection can identify which HDD temperature introduces more error into the model, it does not explain why this is happening or which model is better suited to the actual conditions.

Using the gas consumption data, we ran a house-by-house regression to assess the heating loads during the pre-installation period. Through this process, we were able to identify the set points for each home, and calculate the average set point for all homes with sufficient billing history. This analysis indicated that the average set point was 64.3 ºF. Accordingly, the heating degree days calculated at the base temperature of 65ºF were used for the final model.

8.4.2 Weighting and Model Instability

Another matter of concern was that the top model was based on weighted least squares and returned different estimators than the unweighted model. In the unweighted model, the PY05-participants-only analysis produced unrealistically high savings that disappeared abruptly when the comparison group was added.

The simple pre/post indicated that there were substantial savings among the PY05 program participants (17 therms per year) and approximately the same level of savings was found in the comparison group. In the regression analysis, the results from the PY05 participant group alone, unweighted, suggest that the savings from the DHW package are much higher than is realistic based on the results of our showerhead survey and also DHW savings found in other studies (about 40 therms per year).[53] However, adding the comparison group and explicitly modeling the drop in consumption between the pseudo pre and post periods indicates that the savings from the DHW package are zero. In contrast, the weighted least squares model attributes 8.4 therms per year to the DHW package.

To assess whether there were actually any DHW savings, we conducted a simple pre/post analysis for months with minimal heating degree days (twenty or less). Homes were included in the analysis if they had three or more reads with less than twenty HDD in both the pre-installation and post-installation period. This analysis indicated that the program participants saved about 9 therms per year during these low heating months. Thus, it is clear that there are actual base-level savings from the DHW measures in the participant group, but these savings cannot be anywhere close to 40 therms per year.

The next step was to assess the overall range of savings for the heating-related measures. The simple pre/post was apparently confounded by differences between the PY05 participants and comparison group during the heating months. A PY05 participant-only, unweighted regression model suggested that the savings from the heating-related measures were about three times higher than the weighted least squares model (32 therms on average per home as compared to 10 therms), which indicates savings well over the level estimated in previous four LIEE impact evaluations. However, the comparison group also shows a drop in the heating use over the analysis period.

To further investigate this issue, we ran an unweighted model that combined the PY05 participant and the comparison group and compared the result to the weighted least squares model with the PY05 participants only. The estimators for attic insulation were reasonably stable at the higher use levels where the savings are found. The smaller measures were more variable, but the total program savings for the heating measures were within 15%, with the unweighted model producing smaller savings (9.9 therms per house on average for the weighted least squares as opposed to 8.5 therms for the unweighted model).

[53] The 2001 DEER report estimated savings from installing a low flow showerhead and aerator at 11 to 15 therms per year. Previous LIEE impact evaluations suggest savings for the same measures are in the range of 7 to 12 therms per year.

These finding suggest that there are measurable savings associated with the LIEE program. While the weighted least squares model was intended to minimize the heteroskedasticity in the data set, the fact that the estimators were unstable between the weighted and unweighted models suggests that the model is misspecified and one or more key variable(s) are missing. Without additional information regarding changes over time in these homes, it is not possible to improve the model. However, the weighted least squares tends to downweight the homes with large and unexplained variations in either direction (higher or lower use), and this strategy seems to counteract the instability in the data set and produce reasonable and likely savings estimates.

8.5 Showerhead Survey Results

The showerhead survey was designed to assess the flow rates of the original showerheads and aerators found in the LIEE homes and subsequently replaced with low flow fittings. Eleven randomly-selected program contractors sent the aerators and showerheads they removed from participants' homes to a lab for flow testing. These fittings were subsequently sent to the office of West Hill Energy for a visual inspection of the showerheads. A detailed memo, including sampling, methodology and a complete discussion of findings and results is included in Appendix C. This section of the report provides the background necessary to understand how the results of the testing relate to the overall impact evaluation.

This survey showed that most of the fittings replaced through the LIEE are already low flow, while a smaller number were found to have high flow rates. A small sample of the LIEE replacement showerheads were tested and showed greater variability in flow rates than would be expected. In some cases, the showerhead that was removed might have had a lower flow rate than the new, low flow replacement. In addition, external research indicates that higher flow showerheads are often throttled back by use of the shower control, and thus the savings from the replacement of these items is likely to be somewhat less than anticipated.

These results indicate that the savings from replacing showerheads and aerators with low flow fittings are likely to vary substantially from one house to another, and that some homes may actually see an increase in energy use due to the fact that the replacement showerhead has a higher flow rate than the original one. House-to-house variability is further exacerbated by the wide range of usage patterns associated with the number of occupants in the home, the condition of the water heating equipment and personal habits. In combination, these factors explain the difficulties in estimating the savings from DHW conservation measures encountered in the 2002 impact evaluation.

These findings have implications for the 2005 impact evaluation. The wide variation in savings from one home to the next will make it difficult to estimate measure-level savings using billing analysis. Consequently, the ability to apply engineering methods is a critical component in assessing the validity of the results from the billing analysis and for determining program savings. The flow rates at specific pressures from this component of the study were combined with information from the on-site survey and external sources to estimate the savings from showerheads using engineering algorithms, as explained in Section 8.7, Integration of Results.

These conclusions are supported by a combination of the tested flow rates and the visual inspection of the showerheads, as discussed below.[54]

1. *Mean and median flow rates are relatively low.*

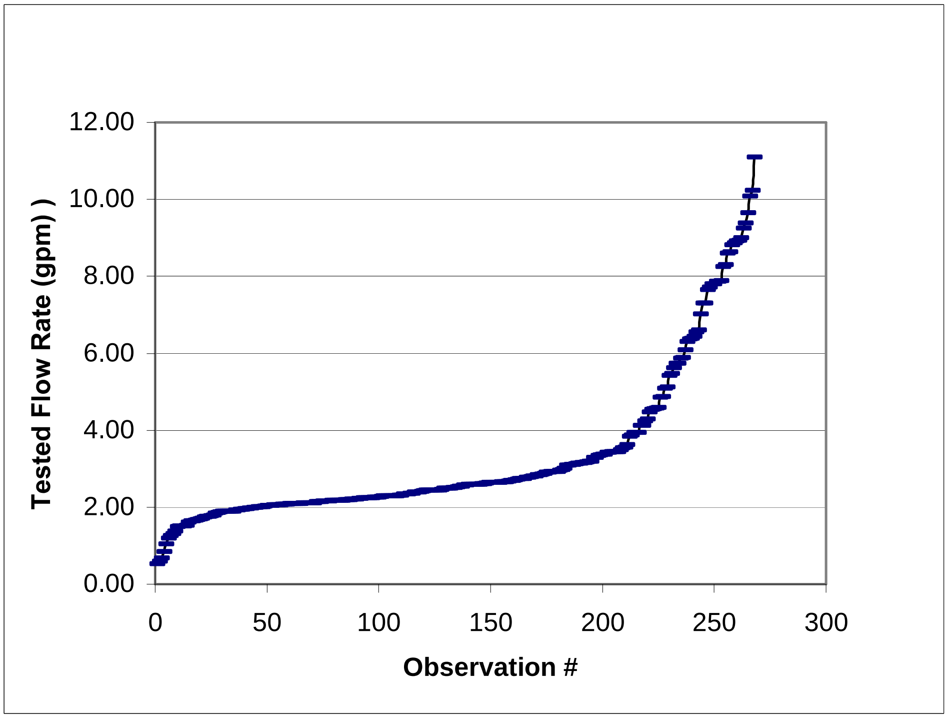
   The mean flow rate for the existing showerheads at 80 psi at the 90% confidence level is 3.32 gpm +/- .32. For aerators, the mean flow rate is 2.68 gpm +/- .31 at 60 psi. The medians are 2.65 gpm for showerheads and 1.96 for aerators. Means, medians, standard errors, minimums and maximums by contractor are provided in Attachment A.

2. *The majority of showerheads and aerators removed were low flow (defined as 3.0 gpm or less), but a few had high flow rates.*

   About 65% of the showerheads tested at 3.0 gpm or less at the highest pressure setting (80 psi) and 46% of the showerheads tested at 2.5 gpm or less at 80 psi.. Figure 8-1 illustrates the distribution of the flow rates for showerheads tested at 80 psi.[55] Almost 60% of the aerators had a tested flow rate of 2.0 gpm or lower at 60 psi, although only 10% tested at or below 1.5 gpm.

[54] Unless otherwise noted, all aggregated results are weighted to account for the cluster sampling. The weighting factors were developed based on the volume of products installed by each contractor.
[55] Graphs showing flow rates for each showerhead are not weighted. Consequently, aggregated values estimated from the graphs may not match the weighted results given in the text.

Figure 8-2: Showerhead Flow Rates at 80 psi



3. *Some low flow devices were modified to allow for greater flow.*

   About a third of the lower flow showerheads (less than 3.0 gpm) showed visible signs of mineral deposits that could impede the flow. The visual inspection indicated that a number of the fittings with low *listed* flow rates and high *tested* flow rates had been modified to allow for greater flow. Almost half of the showerheads with a *listed* flow rate of 2.5 gpm or less and a *tested* flow rate greater than 5 gpm were also found to have visual signs of mineral build up.

   This finding suggests that modifications to, or removal of, the low flow apparatus may be related to plugging of the fittings. However, less than 10% of the showerheads tested at less than or equal to 1.5 gpm at 60 psi, suggesting that excessively low flow rates are not prevalent.

4. *Flow rates for the replacement, low flow fittings are more variable than expected.*

   Six of the contractors provided examples of the low flow devices that they install through the program, for a total of thirteen showerheads and six aerators.[56] Four of the thirteen showerheads had tested flow rates between 2.5 and 3.0 gpm at 80 psi, and one adjustable showerhead had a maximum flow rate of 4.5 gpm. In addition,

[56] All six sent in showerheads, but only two contractors provided aerators.

seven of the thirteen tested below 2.0 at 40 psi.[57] A tested flow rate above the LIEE requirement of 2.5 gpm at 80 psi was recorded for one of the six aerators. These results suggest that there may be quality concerns regarding the new products installed.

The mean flow rates for the replacement, low flow showerheads and aerators are 2.37 and 2.12 gpm, at 80 and 60 psi respectively.[58] Dropping the aerator with the highest flow rate (2.92 gpm) reduces the average flow to 1.96 gpm. With these replacement flow rates, the average reductions in flow rate are .95 gpm for showerheads at 80 psi and .56 gpm for aerators at 60 psi. If the high flow aerator is excluded, the savings increase to .72 gpm.

5. *Pressure level has less of an impact on the flow rates of the low flow devices than higher flow fittings.*

   In general, the differing pressure levels did not have a large impact on the flow rate of the low flow showerheads. The increase in flow rate at higher pressures was much more pronounced for the showerheads using more than 3.0 gpm. The difference in flow rates between the lowest and highest pressures is about 1 gpm for the low flow devices and over 3 gpm for the higher flow fittings.

This survey provided some highly useful insights into the issues affecting savings levels for the replacement of existing showerheads and aerators with low flow devices. In the 2002 LIEE impact evaluation, the savings for the DHW conservation package as a whole (which consisted largely of the installation of low flow aerators and showerheads) were difficult to estimate through billing analysis and the estimated savings were surprisingly low. It now appears that this result was due to the prevalence of existing low flow devices.

These findings indicate that both billing and engineering methods are critical for developing reliable savings for these measures. The data from the showerhead survey were combined with information collected from the on-site survey to develop a savings estimate for low flow showerheads that was then compared to the estimated for the DHW conservation package as estimated from the billing analysis. This process is discussed in the Section 8.7, Integration of Results.

[57] LIEE installation standard require that the replacement low flow showerheads have a maximum flow rate of 2.5 at 80 psi and a minimum of 2.0 at 40 psi.
[58] The flow rate for the showerheads is weighted to account for the relative volume of fittings replaced by the six contractors who provided these items. Since aerators were only provided by two contractors, no weighting was performed.

8.6 On-Site Survey Results

This section of the report provides a discussion of the results of the on site surveys of participant homes conducted in Phase II of the study. It is divided into two sections and is intended to provide an overview of the results as they relate to the overall impact evaluation. The first section covers most of the issues related to the estimation of program impacts, such as measure retention and house-specific and behavioral influences on energy consumption. The second section summarizes the information collected through the survey which provides some insight into non-program influences on energy use. The entire report on the on-site survey is included as Appendix D.

8.6.1 Program-Related Issues Affecting Impact Results

The primary purpose for fielding this study was to inform the results of the billing analysis and improve the reliability of our impact results. The sets of questions on measure retention and house-specific and behavioral issues were designed to provide the information needed to interpret the results of the billing analysis. In addition, specific data were collected to enable the calculation of savings for lighting and low flow showerheads using alternative methods.

This section presents the results from these components of the survey, organized by end use. Heating and cooling measures are discussed first, followed by lighting, refrigerators and hot water conservation measures. Please refer to the discussion of data collection methods in Appendix D for more detail regarding the specific strategies employed for obtaining the data and implications for interpreting the results.

8.6.2 Heating and Cooling Measures

One may expect the retention rate for heating system, cooling system and shell (air sealing and envelope) measures to be quite high. Verifying the retention of these items turned out to be surprisingly difficult. Many participants could not recall receiving the envelope and air sealing measures. These measures, however, may not be noticeable to the participant and easily forgotten. In addition, while the auditors may be able to identify some measures that the participant could have forgotten, they could still miss some measures in unusual or hidden locations.

The retention rates for heating system measures were not valid as a result of issues with utility measure level data. SoCalGas's designators for repair and replace were reversed and a number of respondents, who were marked as having received a new heating system, actually had their existing system repaired. Consequently, when our auditors asked participants if they recalled having a new heating system installed, the survey respondents (correctly) answered "No," thus resulting in an artificially low retention rate. In addition, PG&E's data set did not include heating system repair and replacement measures.[59]

The survey responses relating to the cooling measures indicate that the vast majority of installed items are in place.

8.6.2.1 Heat system use

The responses to the heating system questions suggest that heating system use is minimal among many LIEE participants. Table 8-7 breaks out the heating consumption patterns by region. When interpreting these results, it is important to note that there were only five homes in the desert region, which is an insufficient sample size to support statistical inferences. None of the survey participants were located in the sparsely populated mountainous areas (climate zone 16), where the winters are substantially colder.

Table 8-7: Heating System Use by Region[60]

	Totals	Central to North Coast	Southern Coast	Inland/ Central Valley	Desert[61]
Not working/No Heater	*135*	*6%*	*20%*	*9%*	*0%*
Do not use/30 days or less	*355*	*36%*	*37%*	*33%*	*35%*
Not Working	121	4%	18%	9%	0%
No Heater	14	3%	2%	0%	0%
Do not use	118	21%	11%	5%	31%
30 days or less	237	15%	25%	28%	4%
31 to 90 days	358	29%	35%	42%	35%
91 to 120 days	135	22%	9%	15%	31%
More than 120 days	14	5%	0%	1%	0%
Unspecified	3	1%	0%	0%	0%
Total # of Homes (per 1,000)	1,000	210	492	287	10

Almost half of the households do not have a working space heater, do not use their heating system at all or only use it for 30 days or less per year. For some participants, this low level of heating may reflect the mild climate. In other cases, low income residents may sacrifice comfort for lower operating costs.

[59] Since these issues were identified, SoCalGas and PG&E have provided corrected program- and measure-level data sets for the PY2005 program participants. These corrected data sets were used for the billing analysis.
[60] CEC Title 24 climate zones one through 6 are included in the "Central to North Coast" category. Zones six through nine cover the "Southern Coast." The "Inland/Central Valley" consists of zones ten through thirteen, and fourteen and fifteen are combined to create the "Desert" category.
[61] Only five of the surveyed homes were in the "Desert" region.

Table 8-7 shows that homes with no heating system or a non-functional system are much more prevalent along the southern coast, where the climate is quite mild. Most of these homes did not receive heating system repairs or replacements through the LIEE Program.[62] About 36% of the survey respondents reported using their heating systems thirty days or less a year across all four regions. This finding is consistent with auditor reports that some visited homes were quite cool inside and the occupants were wearing multiple layers to stay warm.

From the questions regarding the time of day of heating use, it appears that many people use their heat in the mornings and very little over the course of the rest of the day. The questions on thermostat use indicate that 60% of the surveyed participants manually adjust the thermostat as needed and 5% have a programmable setback thermostat.

In combination, these results suggest that heating system use is low among a large segment of the population represented in this sample, leading to smaller than expected savings. Consequently, the small signal-to-noise ratio (the ratio of expected savings to monthly energy use) will make it more difficult to estimate the savings from heating-related measures from a billing analysis for the segment of the state with the largest population and highest numbers of program participants.

It is possible that heating patterns are substantially different in the desert regions (where our sample size was too small to draw conclusions) and in the mountainous areas in the western part of the state (where there were few participants and no surveyed homes).

8.6.2.2 Cooling Use

Assessing cooling consumption patterns is more complicated. According to program protocols, only LIEE participants in CEC Title 24 cooling zones eleven through sixteen are eligible for cooling measures, which excluded all of the SDG&E participants in our sample.

Since this survey was conducted during the post-installation period, the possibility that the reported consumption patterns may not reflect pre-installation use must be acknowledged. Notes on the audit form indicated that at least a few participants radically cut back on air conditioning use after the installation of the evaporative cooler.

Table 8-8 below shows the consumption patterns for both the group of participants who received LIEE cooling measures (mostly evaporative coolers) and those who may have been eligible for a LIEE cooling measure but did not receive one.[63]

[62] Of the 12% of participants without a working heating system, 13% were marked as having received heating system measures from SoCalGas. The other 87% apparently did not have their systems repaired or replaced through the program.

[63] "Eligible for an LIEE cooling measure" is defined as participants in CEC Title 24 cooling zones 11 to 16 and having a refrigerant-based A/C system.

Table 8-8: Cooling Patterns by Homes With and Without LIEE Measures

	Received LIEE Cooling Measure		Eligible but Did Not Receive LIEE Cooling Measure	
	# Homes (per 1,000)	% of Homes	# Homes (per 1,000)	% of Homes
Do Not Have Refrigerant-based A/C System	3	6%	NA	
Do Not Use	3	6%	3	6%
10 days or less	7	15%	5	9%
11 to 30 days	16	32%	10	18%
31 to 60 days	18	36%	12	21%
61 to 90 days	2	3%	19	35%
More than 90 days	0	0%	6	11%
Not Working	1	1%	0	0%
Unspecified	1	1%	0	0%
Total	51		56	

This analysis indicates that almost 60% of the LIEE participants with cooling measures turn on their refrigerant-based systems less than 30 days per year and none use the system more than 90 days a year. In comparison, A/C usage is much higher among those participants who were eligible for LIEE cooling measures but did not receive one. Two-thirds of the survey respondents in this group reported running their A/C systems more than 30 days a year, and 11% more than 90 days per year.

Almost 40% of the homes with evaporative coolers in the hotter climate zones either have no refrigerant-based cooling system or report that they do not use their A/C at all, although the vast majority of homes with evaporative coolers installed by LIEE report at least some A/C use.

Evaporative cooler savings are dependent upon behavioral modifications. Unlike refrigerant-based A/C, evaporative coolers require some air flow from the outside, and consequently the A/C and evaporative coolers should not be operated at the same time.

Table 8-9 shows the percent of survey respondents who follow the standard recommendations to keep a window open when using the evaporative cooler and avoid using the A/C and cooler at the same time. The majority of homes with LIEE-provided coolers follow these directions, although these results also suggest that there is room for improvement.

Table 8-9: Evaporative Cooler Behavioral Patterns

	Received LIEE Evaporative Cooler	Have a non-LIEE Evaporative Cooler[64]
Always have window open when cooler in use	65%	40%
Never use cooler & AC at the same time	84%	95%

In total, these finding are contradictory to some degree. The analysis of cooling patterns suggests that the homes with evaporative coolers may well have cut back significantly on cooling use, leading to the conclusion that it may be possible to estimate cooling savings from a billing analysis in the absence of other confounding circumstances occurring during the analysis period.

In contrast, 35% of survey respondents with LIEE-installed evaporative coolers do not consistently keep a window open when the equipment is running and 16% run the refrigerant-based A/C and evaporative cooler at the same time at least occasionally, suggesting there may well be house-specific issues that will effectively degrade the expected savings.

8.6.3 Lighting

Table 8-10 below provides the persistence by number of items installed for lighting products. This analysis reflects the information provided by the survey respondents and indicates that about 35% of the CFL products indicated by the utilities as having been installed in these homes was missing.

The reasons for the absence of the items are also listed, to the extent that this information was available. The survey was not entirely successful at eliciting a description of the reasons why the items were not found in place. However, it is interesting to note that at least 13% of all of the utility-reported CFL bulbs and fixtures had failed by the time of the on site survey. This type of high failure was previously noted in the California Multi-family Rebate Program. Low quality CFL's may be a contributing factor to the high failure rate. Another 8% of the utility-reported CFL's were not installed (according to the LIEE participants).

[64] These homes have an evaporative cooler not provided by LIEE and are located in the climate zones where they would be eligible for LIEE cooling measures.

Table 8-10: Measure Retention by Item for Lighting

	CLF Bulbs and Fixtures	
	Total Items Per 1,000 Homes	% of All Items Installed
Total Items Installed	4,101	
Still In Place	2,661	65%
Not Found	1,440	35%
Reason for Absence		
Failed	520	13%
Not like/not used	110	3%
Remodel	11	0%
Not installed	332	8%
Other	70	2%
Don't Know	397	10%

8.6.3.1 Implications for LIEE Lighting Savings

Lighting savings are particularly difficult to estimate from a billing analysis due to the small size of the expected savings in comparison to total use. The results from the previous three LIEE impact evaluations suggest that lighting savings were in the range of 21 to 43 kWh per year.

In the 2002 LIEE Impact Evaluation, we conducted a literature search and placed the savings estimates within the range of values found in other programs. The review indicated that savings from other programs range from 34 to 63 kWh, indicating that the LIEE estimates tend to be on the low end.

At that time, we postulated that this difference could be partially explained by measure retention. A telephone survey conducted for the 2000 LIEE evaluation indicated the retention rate was around 80%.[65] An evaluation of SCE's Direct Assistance Program based on a survey of 1995 participants in SCE's Direct Assistance Program found a 90% retention rate, but separate on-site inspections conducted as part of the latter study showed that the actual number of bulbs in place in participant's homes was only 61% of what the tracking system indicated.[66]

[65] Xenergy. 2002. Volume I: Impact Evaluation of the 2000 Statewide Low-Income Energy Efficiency (LIEE) Program. Southern California Edison, Southern California Gas Company, San Diego Gas & Electric Company, Pacific Gas & Electric Company.

[66] Xenergy, Inc. 1997. Impact Evaluation of the 1995 Residential Direct Assistance Program. Southern California Edison.

Another possibility that we considered was that the actual hours of use may also be somewhat lower for LIEE thus lowering the expected savings. The SCE study mentioned in the paragraph above also included data loggers on 205 light fixtures with CFL replacements to capture hours of use, and found average use to be 3.5 hours per day. Our on-site survey (based on self-reports) suggests the LIEE usage levels are lower, with an average of 2.8 hours per day.

8.6.4 Refrigerators

The measure retention rate for refrigerators was quite high, with 95% of the LIEE refrigerators found in place from both the participant's and auditor's perspectives. A few survey respondents indicate issues with the refrigerators, including size (too small), malfunctions and one that failed. A small number of survey respondents elected to give their new refrigerators to other family members.

The savings from refrigerator replacements as estimated from the billing analysis conducted in the 2002 LIEE impact evaluation were reasonable and robust. Thus, no other detailed information regarding refrigerator use was pursued.

8.6.5 Hot Water Conservation Measures

About 95% of the surveyed homes had at least one of the hot water conservation devices still installed at the time of the audit, both by the auditor's and participant's accounting. However, about 20% of homes were *missing* one or more of the hot water measures.

Table 8-11below provides the retention rate for low flow showerheads and aerators, and the reasons for the removal. These measures were selected for additional analysis due to the high number of items installed per home. About 80% of the showerheads and aerators were found in place.

At least 4% of all of the showerheads and 5% of aerators claimed by the utilities either failed or were not installed, according to the survey respondent's account. Another 5% of the showerheads and 2% of aerators were either not satisfactory to the participant or were installed in unused locations.

Table 8-11: Measure Retention by Item for Hot Water Measures

	Showerheads		Aerators	
	Total Items per 1,000 Homes	% of All Items Installed	Total Items per 1,000 Homes	% of All Items Installed
Total Items Installed	842		1363	
Still In Place	675	80%	1087	80%
Not Found	167	20%	275	20%
Reason for Absence				
Failed	11	1.3%	19	1.4%
Not installed	22	2.6%	51	3.8%
Not like/not used	39	4.6%	30	2.2%
Remodel	22	2.6%	15	1.1%
Don't Know	74	8.8%	160	11.7%

In addition to the retention issues, about 4% of the LIEE low flow showerheads had a measured flow above the LIEE standard of 2.5 gpm.

8.6.6 Non-Program Influences

Savings estimates from a billing analysis can be affected by many factors that have absolutely nothing to do with the LIEE Program, most of which cannot be quantified. However, the on-site survey provides some insight into two confounding issues identified and discussed by our team:

- customer purchases of energy-related equipment and
- participation by LIEE households in other efficiency initiatives, such as those offered at the state or municipal level.

The purchase of new or replacement energy-related equipment can result in changes to the baseline energy use. Even if LIEE participants are not purchasing the most energy efficient option, it is likely that a newer device will use less energy than the one previously in place. This type of activity adds noise to the billing analysis and makes it more difficult to estimate savings. When a comparison group is included in the analysis and such purchases are included in the baseline energy use, the resulting savings estimates attributed to the LIEE Program will be smaller because they will incorporate some net effects.

Installation of additional, unknown measures from other efficiency programs may well result in biased savings estimates if they are coincident with the installation of the LIEE measures. If they were randomly distributed throughout the analysis period (the most benign possibility), they would add noise to the billing analysis.

These issues were addressed through the on-site survey as follows:

- The source of all major energy-related equipment was identified as LIEE, Customer Purchase, Existing, Other Program or Unknown. "Customer purchase" indicated that the survey respondent identified the item as something they had bought. "Existing" meant that the equipment was in place when the survey respondent moved into the home.
- Survey respondents were asked if any other LIEE measures had been installed and whether they had participated in any other programs. This process elicited information that can be useful in assessing the prevalence of participation in other programs.

The remainder of this section discusses the customer purchases of CFL's, refrigerators and cooling equipment, and the identification of additional measures.

8.6.6.1 Purchases of CFL's

Almost 40% of the survey respondents purchased one or more CFL's outside of the LIEE Program. It was not feasible to collect detailed data on the reason for each purchase or to determine the timing of the purpose.

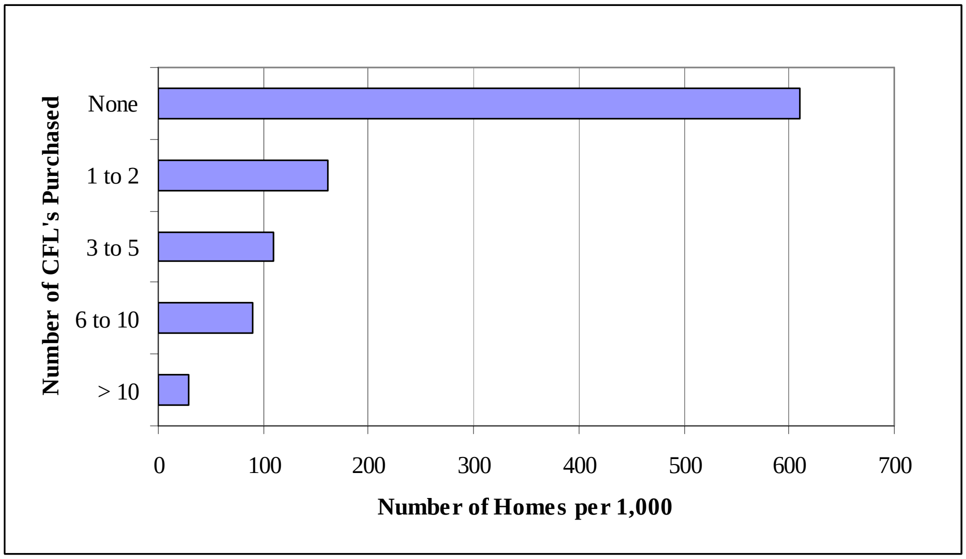
Table 8-12 shows the various ways participants obtained the CFL's. On average, customer purchases accounted for about 30% of the CFL's found in the surveyed homes. The average wattage per bulb for those purchased directly by the customer is higher than that of the LIEE-installed bulbs.

Table 8-12: Source of CFLs

	Mean Number of CFLs per Home	Mean Watts per Fixture	Mean Hours Use per Day
LIEE Supplied	2.9	21	3.0
Other Program	0.1	37	2.7
Customer Purchase	1.6	29	2.7
Other	0.2	24	3.5
All Sources	4.8	25	2.9

Figure 8-3shows the number of households (per 1,000) purchasing CFL products outside of the LIEE program.

Figure 8-3: Households Purchasing CFLs Outside LIEE (Self-Reported)



Customer purchases can occur for several reasons:

- customers may purchase more CFL’s to install in additional fixtures not covered by the LIEE products
- customers may purchase CFL’s to replace LIEE-installed CFL’s that fail or are broken
- customers may purchase CFL’s to replace LIEE-installed CFL’s that were not satisfactory for some reason, such as providing too little light

Although it was not feasible to attempt to tease out this level of information from the on-site survey, some of the data collected may offer some insight into these issues.

Table 8-13compares the utility-reported number of CFL’s with the total number of CFL’s found in the homes.[67] These results are reported for all homes that received CFL’s through the program as reported in the utility tracking systems.

[67] In this case, “total number of CFL’s” refers to customer purchases and LIEE bulbs. CFL’s that were already in place when the survey respondent moved into the home were not considered, since these would have no effect on the impact evaluation results. There were also a very small number of bulbs installed through other programs that were excluded for logistical reasons and would have virtually no impact on the results reported here.

Table 8-13: Distribution of Customer-Purchased and LIEE CFL's by Home

	Homes with LIEE Lighting (Utility Reported)
No CFL's reported by the auditor	14%
Auditor found fewer CFL's than Utility-Reported	40%
Auditor found same # of CFL's as Utility-Reported	13%
Auditor found more CFL's than Utility-Reported	33%
Number of Households (per 1,000)	778

This analysis suggests that customer purchases are motivated by a variety of factors. In about 33% of the homes, the combined total of CFL's is higher than the number of LIEE bulbs installed, indicating that these participants are adding CFL's to new locations. In the 53% of homes where the same or fewer CFL's were found, it is certainly possible that customer purchases are being used to replace LIEE bulbs.

These results suggest that the purchase of CFL's is common among a large minority of LIEE participants. As a result, separating LIEE savings from other participant activity may not be possible.

8.6.6.2 Refrigerator Purchases

Almost half (47%) of the refrigerators and freezers found in the LIEE homes were purchased by the survey respondent. The timing of the purchases is unknown, but it is clear that many LIEE participants are in the position of having to purchase this major appliance.

8.6.6.3 Purchases of Cooling Equipment

Survey respondents also identified the source of their cooling units. Reviewing these responses indicates that about 35% of the cooling units found in the homes of the survey respondents were purchased by the participant. Room A/C units are the most prevalent, accounting for almost 60% of the customer-purchased units.

These results indicate that customer purchases of new air conditioning equipment are not uncommon. Even if the new equipment is not high efficiency, it is still likely to be an improvement over the old unit. It is also possible that some of these purchases represent additional cooling units in the home, resulting in an increase in load. The estimates of gross savings from cooling measures could be overestimated if a new more efficient unit is purchased to replace an older unit after the installation of the LIEE measures. On the other hand, if an *additional* cooling unit is purchased after the installation of the LIEE measures, the savings could be underestimated. Finally, if the members of the comparison group are to a larger extent engaging in any of these purchase behaviors, our efforts to control for larger social and economic trends will complicated.

8.6.6.4 Additional Measures

Almost a quarter of the survey respondents indicated that they received additional measures from LIEE, beyond those found in the utility's tracking systems. If these extra measures are common and are installed during the analysis period, they could affect savings estimated through the billing analysis. The bias introduced by this effect could be in either direction, depending upon the timing of the installations. The analyses described below were conducted to try to determine the magnitude of the issue and the relative importance of possible contributing factors.

There are five possible reasons for participants in this sample identifying additional measures:

1. The participant received LIEE measures outside of the program year 2005. Often some of the larger measures, such as refrigerators or evaporative coolers, are installed after the initial energy assessment when the CFL's are put in.

2. The participant may have received measures from another program, such as LIHEAP. In some cases, the LIEE contractor also provides services for another program and, in a single home, some measures could be charged to LIEE and some to a different program. In this case, the participant could easily conclude that LIEE was responsible for all of the measures.

3. As discussed above, SCE and SoCalGas offer joint services in some areas, but we were unable to match up all participants served by this joint effort. Consequently, our records would have shown that only SCE's or only SoCalGas's measures were installed, but the participant could have been served by both utilities.[68]

4. The utility tracking records are in error. One issue already identified is the reversal of repaired and replaced heating systems for some of SoCalGas's participants. In addition, PG&E's measure-level data set was missing space and water heating replacement/repair measures. Both of these data inconsistencies were corrected prior to conducting the billing analysis.

5. The survey respondent's memory is in error. They may have incorrectly identified extra measures or incorrectly attributed measures from a different energy efficiency program to LIEE..

Some of the survey data is helpful for assessing the relative impacts of these contributing factors.

The findings from the on-site survey are summarized in Table 8-14 below. The magnitudes are estimated using the known percentage of homes in the sample, and then adding the portion of the homes with unexplained extra measures, where appropriate.

[68] SoCalGas's intial program data set used for sampling was missing about one quarter of the PY2005 program participants. This omission was corrected in March, 2007.

Table 8-14: Summary of Implications of Additional Measures

Contributing Factor	Issue	Possible Magnitude	Action Taken
Measures installed in other years	Unknown measures installed during analysis period may introduce a bias.	3% to 9% of LIEE homes	Utilities have provided lists of all measures installed in PY05 homes from 2004 through 2006
Participation in other conservation programs	Unknown measures installed during analysis period may introduce a bias.	2% to 8% of LIEE homes	Contractors who work for both LIHEAP and LIEE will be identified.
SoCalGas/SCE overlapping participants	Some participants could not be matched. Affected on-site sampling and interpretation, but not the billing analysis.	None	None needed.
Errors in utility tracking systems	Incorrectly identified measures will affect billing analysis.	1% or more of LIEE homes	Systematic problems with SoCalGas and PG&E measure data have been corrected.
Error by survey respondent	Respondents may have incorrectly identified extra measures or forgotten to report extra measures.	Unknown	None.

8.7 Integration of Results

Due to concerns regarding year-to-year variations in savings in previous evaluations, particularly at the measure-level, this study was designed to provide supplemental information to assess the results of the billing analysis and allow for the estimation of savings for some measures by alternative methods. In this section, each end use is reviewed in the context of the reliability of the regression results as assessed by internal validation techniques and a comparison of the regression results to alternative savings calculations (external validation), where possible. In short, the synthesis of results into the final measure-level estimates is explained.

This section is organized by measure or end use. All of the gas savings were estimated from the regression model. Alternative methods were used for the electric measures that could not be reliably estimated from the regression model, as summarized in Table 8-15 on the following page.

8.7.1 Lighting

Lighting estimates are available from the regression analysis and were also estimated using engineering algorithms in conjunction with data collected during the on-site survey and other external sources of information. While the per bulb estimates for this program from the last three impact evaluations have generally been low, the current estimate from regression analysis is lower than the previous lowest estimate of 22 kWh per year by a wide margin at 11 kWh, with a 90% confidence interval of 6 to 16 kWh.

8.7.1.1 Alternative Lighting Estimate

Sufficient information was collected through the on-site survey to support an alternative method of estimating savings from lighting products, using standard algorithms based on the hours of use, reduction in wattage and the percentage of bulbs assumed to remain in place. The formula is given below:

$$\text{kWh savings/year} = (W_{old} - W_{new}) \times \text{Hours} \times \text{ISR} \times \text{SRF} \times (1\ \text{kW}/1000\ \text{W}) \quad (1)$$

where W_{old} is the wattage of the original bulb,
W_{new} is the wattage of the CFL replacement bulb,
Hours is the hours of use per year,
ISR is the in-service rate, or percent of CFL's assumed to remain in place,
SRF is the self-reporting factor (adjusts for errors in self-reported hours of use).

From the on-site survey, we can make estimates some of the critical inputs, such as the hours of use and the in-service rate, and other inputs can be estimated from external studies.

Table 8-15: Summary of Savings for Electric Measures

Measure	Regression Result	Showerhead/ On-site Estimate	DEER/ External Studies	Previous LIEE Evaluations	Source of PY05 Savings Estimate
Lighting (per CFL)	11 kWh	22 kWh	36 kWh	22 - 43 kWh	Adjusted to be between regression and on-site estimate, at 90% upper confidence bound of regression result
Refrigerators	760 kWh	None	None	645 to 795	Electric regression model
Attic Insulation (heating)	252 kWh	None	180 kWh (2005)	35 - 288 kWh	Electric regression model
Attic Insulation (cooling)	23 kWh	None	None	44 - 208 kWh	Electric regression model
DHW Package	Not estimated	171 kWh (showerhead)	78 - 608 kWh (2001)	30 - 240 kWh	Convert savings from gas regression model
Cooling Measures	161 kWh	None	333 – 5056 kWh (2001)	98 - 571 kWh	Electric regression model
Air Sealing/ Envelope measures	Not estimated	None	None	10 - 56 kWh	Convert savings from gas regression model

Table 8-16 shows the overall statistics on the number of fixtures and the average hours per day that lamps are in use from the data collected during the on-site survey. CFLs are in use an average of 2.9 hours per day.

Table 8-16: Number of Fixtures, Total Wattage, and Average Hours of Use Per Lamp from the On-Site Survey

	All Types	Fluorescent *		Incandescent	
	Mean	Mean	Pct.	Mean	Pct.
Number of Fixtures in Home	13.6	6.1	45%	7.5	55%
Total Watts of Lighting per home	547	155	28%	391	72%
Average Hours per Lamp per Day	2.8	2.9		2.8	

**includes both CFLs and tubes*

The measure retention rate is a good indicator of the percentage of bulbs found in place. The on-site survey indicates that measure retention is approximately 65% at the per bulb level, which provides a reasonable estimate for the in-service rate.

The difference in wattage can be calculated from available data on CFLs and replaced bulbs.[69] A recent California lighting study concluded that self-reported hours of use for residential lighting are overstated by about one third.[70] Given that the on-site information is collected directly from the participants and relies on self-reports, the hours of use were corrected for this self-reporting bias.

A preliminary estimate of savings per bulb can be calculated by combining all of this information as follows:

kWh savings per bulb = 48.7 W x 2.9 hours/day x 350 days/year x
.65 in-service rate x .667 self-reporting factor x
(1KW/1000W)

= 21 kWh

[69] In the interim on-site reports, an estimate of 65 KW was used based on the methodology described in a memo from Glacier Consulting Group, LCC. The West Hill Energy team was concerned that this estimate was too high because this method based on assumptions about replacements for specific wattages of the CFL's installed and, given that the LIEE program installs a limited range of CFL's, it is likely that the correlation between the wattage replaced and the CFL wattage is weaker than assumed. The current estimate of 48.7 W is from the 2005 CFL Metering study cited in the next footnote. It is also consistent with a 2003 residential lighting study conducted in New England, i.e., the Impact Evaluation of the Massachussetts, Rhode Island and Vermont 2003 Residential Lighting Programs, produced by Nexus Marketing Research, Inc., dated October 1, 2004.

[70] CFL Metering Study Final Report. Prepared for Pacific Gas & Electric Company, San Diego Gas & Electric Company and Southern California Edison. Prepared by KEMA Inc., Oakland California. February 25, 2005, page 1-5.

8.7.1.2 Synthesizing the Lighting Results

The difference between the engineering estimate and the regression result is marked. Lighting savings are quite small in comparison to total use and can be difficult to estimate through a regression analysis. The relatively low retention rate suggests that the dummy variable indicating the installation of lighting measures is unreliable for a significant number of homes, which introduces error into the analysis and is likely to exert an downward bias on the estimator. In addition, the on-site survey indicates that many participants are purchasing CFLs outside of the program, which could be occurring throughout the analysis period and tends to make lighting use more variable. Also, model diagnostics indicate that the lighting variable in the regression model exhibits some degree of collinearity, which is likely related to the fact that CFLs are installed in almost all of the LIEE households.

These results would point to the possibility that the lighting savings from the regression model could be biased, and the bias is more likely to be downward. However, the total household savings from the regression model should be reasonably robust, and since lighting comprises such a large part of the program savings, one would expect these savings to be found in the billing analysis. Given the major impact on the total program savings for even modest increases in the kWh per CFL savings estimate, we are reluctant to adjust this savings number by a large margin. We have adopted a compromise position of adjusting the savings per CFL upward from 11 kWh to 16 kWh per year, the upper bound of the 90% confidence level of the estimate from the regression model.

8.7.2 DHW Conservation Package

The DHW package includes low flow showerheads and aerators, pipe insulation and tank wraps. Of these items, low flow showerheads and tank wraps are likely to have the greatest savings. While the showerheads are installed in most homes, tank wraps are rarely installed, suggesting that the primary source of the savings on average per home is likely to be associated with the low flow showerheads.

The gas savings for the DHW package are estimated to be 8.4 therms from the regression analysis. The electric model did not produce a reliable estimator for the package of DHW measures.

8.7.2.1 Alternative Estimate for Low Flow Showerheads

Energy savings from showerheads can be calculated from the following equation:

Energy savings = Hot Water Saved (gal) x ΔT x C_p x CF x ISR / Eff_{WH}

where Hot Water Saved (in gallons) is the reduction in hot water use due to the installation of the low flow fitting,

ΔT is the change in temperature from the inlet water to the water coming from the showerhead,

C_p is the specific heat of water,

CF are conversion factors to change the units from gallons of water to pounds and from Btu's to kWh or therms,

ISR is the in-service rate, or percent of low flow showerheads assumed to remain in place, and

Eff_{WH} is the efficiency of the water heater.

The reduction in water use is estimated through a series of steps, as listed below:

- determine the percentage difference in flow rates between the existing and new showerheads,
- make any necessary adjustments for throttling and spigot leakage,
- estimate the average water use per showerhead, and
- apply the percentage difference in flow rates (adjusted as needed) to the average water use per showerhead.

The other inputs are either conversion factors, known constants, or estimated from external information. The derivation of each of the inputs is described below.

Pre- and Post-Installation Flow Rates

In an earlier component of the study, showerheads removed from LIEE participants' homes were sent to a testing facility and the flow rates were measured at flowing pressures of 20, 40, 60 and 80 pounds per square inch (psi). If we know the flowing pressure in LIEE homes, this information can be used to calculate the average pre-installation flow rate of the existing showerheads. The average flow rate of the LIEE fittings is another key input.

The on-site study was designed to fill in these missing pieces of information, as well as provide additional data for estimating the savings from showerhead replacement under the program. Wherever feasible, showerhead flow rates and flowing pressure were measured by the on-site auditors, as described in Appendix D.. This information from the on-site survey was combined with the earlier bench-testing to estimate the reduction in flow.[71]

As Table 8-17 shows, the replacement showerheads provided by the program averaged 1.95 gallons per minute of flow. There was also a difference in flow rates measured by the two methods: the meter measurements yielded lower flow rates on average than did the flow bag measurements. Whether this is due an inherent bias in measurement by the two methods, or simply represents an underlying difference in the showerheads that were measured by each method, is unknown.

[71] Please note that the two data sets came from different households.

Table 8-17: Measured Showerhead Flow for LIEE Showerheads

	Average Flow (gpm) (n=246)	Standard Error
Overall	1.95	0.05
Measured with meter (n=130)	1.78	0.08
Measured with flow bag (n=116)	2.10	0.06

*as reported by the participant

The measured pressures, averaged over all surveyed homes where the measurements could be made, are presented in Table 8-18. This analysis includes measurements on both LIEE and non-LIEE showerheads.

Table 8-18: Measured Static and Flowing Pressures for all Showerheads

	Pressure (psi)	Standard Error
Static Pressure (No flow) (n=196)	63.9	3.4
Flowing Pressure (Full-on) (n=194)	49.7	3.3

The bench testing was done at four pressure levels, i.e., 20, 40, 60 and 80 psi. We interpolated the flow rates from the bench-test data to reflect flow at 50 psi, representing the approximate average flowing pressure found from the on-site study. This adjustment results in an average pre-replacement showerhead flow of 2.79 gpm, compared to 1.95 gpm for the replaced showerheads, or a 30 percent reduction in flow rate.

Adjustments to the Flow Rates

A complicating factor in this analysis is that the flow measurements were made at full flow, but prior field research has demonstrated that people often do not shower with the showerhead in the full-on position.[72] Using data provided by Proctor Engineering for a PGE field study in which both full-on and occupant-determined showerhead flow rates were measured for 443 homes, we derived the following functional relationship between measured full-on flow and the actual flow setting used by occupants during showering:

As-used flow = full flow (full flow ≤ 1.5 gpm)
As-used flow = 0.5*full flow + 0.75 (full flow > 1.5 gpm)

In theory, the analysis also needs to take into account that some shower controls do not allow for adjustment of the flow rate. However, the on-site data showed that nearly all households had controls that allowed for both flow and temperature control.
Spigot leakage can also affect the savings from low flow showerheads. The low flow fittings tend to increase the pressure behind the showerhead and can exacerbate any

[72] "Savings and Showers: It's all in the Head," *Home Energy Magazine*, July/August 1994. Available from: http://www.homeenergy.org/archive/hem.dis.anl.gov/eehem/94/940713.html

existing problems with spigot leakage. However, this issue does not appear to be significant since less than 3% of the LIEE homes have any significant spigot leakage, even with the low flow devices.

When occupant throttling of high-flow showerheads is taken account, the estimated average pre- and post-replacement showerhead flow rates are reduced to 2.09 and 1.95 gpm, respectively, representing an 18% decrease in flow on average.

Average Water Use per Showerhead

A recent end-use study of water consumption in 33 Bay area homes provides an estimate of 12 gallons per capita per day for showering water consumption.[73] Applied to the recorded average of 3.44 occupants per home for on-site homes that received a showerhead replacement and adjusting for hot water use, this yields an estimate of 41.3 gallons per day of water use per household.

Total Water Reduction

Applying the 18 percent reduction in flow rate discussed above (and adjusting for the fact that not all showerheads are replaced in all homes that receive showerheads), we thus estimate that replacement showerheads save about 7.2 gallons of water per day per household[74], or about 5.5 gallons of water per day per replaced showerhead, since the program replaced an average of 1.32 showerheads per household where a replacement occurs.

Other Inputs

Translating these results into energy savings also requires the average inlet and shower temperatures of the water. The water temperature at the inlet and shower are assumed to be 62º and 105ºF, respectively, giving a change in temperature of 43ºF.[75]

Savings Estimate

Energy savings =

5.5 gallons water saved/day x 43ºF x 1Btu/ºF lb x 8.33 lb/gal x .80 ISR / (.98 WH efficiency x 3413 Btu/kWh)

= 171 kWh

[73] "Residential Indoor Water Conservation Study: Evaluation Of High Efficiency Indoor Plumbing Fixture Retrofits In Single-Family Homes In The East Bay Municipal Utility District Service Area," Aquacraft, Inc., July, 2003.

[74] 41.3 gallons per day x 18% reduction x 95% of showerheads replaced by the program = 7.2 gallons per day.

[75] The cold water temperature is based on the 10-year average annual outdoor temperature for all participants receiving a water heating measure in 2005. The shower temperature is referenced in a LBL study and supported by a small (unpublished) field survey conducted by the Energy Center of Wisconsin.

These daily hot water savings estimates translate into an estimated 7.3 annual therms and 171 kWh of annual energy savings per showerhead for gas and electric water heat.[76]

8.7.2.2 Synthesizing the DHW Conservation Package Results

The regression model and engineering methods produce results that are reasonably consistent with each other and the previous LIEE evaluations. The 8.4 annual therm savings from the gas regression model seem highly plausible, given that showerheads are assumed to produce the bulk of the savings and the alternative estimate suggests that these savings are 7.3 therms. Thus, the regression results are used to calculate the program savings for gas.

The electric regression model did not produce a reliable estimator for the DHW conservation package, which is largely due to the high coincidence of electric DHW and space heat, causing variability in the electric use and making it more difficult to assess savings. Unlike the gas model, where it was possible to provide a rough check on the DHW savings by looking at the months with low heating loads, the electric homes often do not have a lengthy seasonal period unaffected by heating or cooling loads.

It is reasonable to assume that these EDHW measures accrue savings and that these savings may not show up in the average household savings from the regression model due to the very low incidence of electric DHW. For this reason, we have estimated the savings for the electric DHW package by converting the gas savings to kWh and correcting for the different efficiencies of gas and electric water heating equipment, as shown below.

DHW kWh savings = 8.4 therms x 100,000 Btu/therm / 3,412 Btu/kWh
x .78 gas recovery efficiency/ .98 electric efficiency

= 196 kWh

8.7.3 Attic Insulation

Savings for attic insulation were estimated from both the electric and gas regression models, resulting in average savings of 252 kWh and 59 therms for heating and 22 kWh for cooling. The range of savings from previous LIEE evaluations is wide, from 35 to 288 kWh for electric heat, 10 to 59 therms for gas and 44 to 208 kWh for cooling. The 2005 DEER database indicates that savings from attic insulation are about 180 kWh and 41 therms.

The regression estimates for the electric and gas heating savings are within the range of the previous LIEE evaluations and 40% and 45% higher than the DEER savings for kWh and therms, respectively. However, the cooling savings are lower than found in the earlier

[76] We assumed that gas water heaters have a recovery efficiency of 78%, and electric water heaters have a recovery efficiency of 98%.

LIEE evaluations. The estimated cooling savings from previous LIEE evaluations were reported in the 2000 and 2001 impact evaluations conducted by Xenergy (now KEMA).

One major difference between Xenergy's modeling and the current study is that the utilities began tracking the homes with working air conditioners and providing this information at the household level in 2005. In the absence of this information, Xenergy identified homes with cooling based on the consumption patterns. Thus, the regression modeling would be estimating the savings for homes with clearly measurable cooling loads. In the current study, we identified the homes with air conditioning according to the utility designators, which are likely to include homes with a range of cooling loads, some of which may be quite small. This change in strategy may well explain the lower savings number.

The regression results for attic insulation seem to be in a reasonable range and were used to estimate the program savings.

8.7.4 Envelope and Air Sealing Measures

Savings for these smaller measures were part of the output from the gas model, but could not be reliably estimated from the electric model. The gas model indicates savings of approximately 9.5 therms per home, which is within the range of 2 to 11 therms found in the earlier LIEE evaluations. Our literature review did not turn up any other relevant evaluations to provide additional context for these numbers.

The savings from the electric model would lead one to conclude that electric use increased due to these measures, which is most likely due to the fact that most homes with electric space heat also have either electric DHW or air conditioning equipment or both, making the consumption in these homes much more variable.

The gas savings for these measures are estimated from the regression model. In the absence of better information, the electric savings are estimated from the gas results, adjusting for the difference in efficiency between the gas and electric heating systems and also for the difference in the use of electric space heat.

8.7.5 Refrigerators

Refrigerator savings were fairly stable and consistent in the previous evaluations, and were not identified as a targeted measure for this study. The on-site survey indicated that LIEE energy efficiency refrigerators have a high retention rate (95%).

The results of the billing analysis suggest that refrigerator savings are a bit more variable than anticipated. The weighted least square model produced savings of 760 kWh, but the savings from the unweighted model were about 16% lower at 642 kWh. The results from previous evaluations indicate that savings from efficient refrigerators range from 645 kWh per year to 795 kWh. Both of the current estimators fall close to or within this range, making it difficult to know whether one or both estimators are biased. While a recent study of a low income program with refrigerator replacement in Ohio found savings in the range of 800 kWh, it is not clear whether this information is applicable to the LIEE program given the differences in protocols among low income programs operating in other states.[77]

The weighted least squares model was the top-ranked model from the model selection process and is used for most of the other electric measures. Consequently, the estimate from the least squares model was also used for the refrigerator savings.

8.7.6 Cooling Measures

The cooling measures include installing evaporative coolers and replacing room air-conditioners. Measure savings are estimated at 161 kWh from the regression model. The top-ranked model from the model selection process incorporated both of these measures into one variable, pointing to the conclusion that separating the two variables did not represent an improvement to the model.

A number of steps were taken to improve the modeling of cooling measures for the PY2005 evaluation. The first and most crucial action was for the utilities to collect information regarding the presence of working air conditioning equipment in the home and enter this data into the electronic tracking systems. The enhanced data collection allowed us to improve the modeling of cooling measures.

The on-site survey was also designed to gain a better understanding of the use of the new cooling equipment, although this information is qualitative in nature and did not permit alternative savings calculations. The retention rate for the cooling equipment is high and the survey found that many LIEE participants with cooling measures tend to use their air conditioning systems very little. It is not known whether this behavioral pattern was in place before the LIEE cooling equipment was installed.

It is also clear that some of the operating procedures for the evaporative coolers are not thoroughly understood by LIEE participants, with 35% reporting that they use the evaporative coolers with all windows closed at least occasionally and 16% that they sometimes use the refrigerant-based air conditioner and evaporative cooler at the same time.

In aggregate, these findings lead to the conclusion that the savings are likely to be quite variable from home to home and many homes may have low savings due to the restricted use of the cooling equipment. Failure to operate the evaporative cooler and refrigerant-base air conditioning correctly may also degrade savings in some homes.

Previous LIEE evaluations estimated savings for evaporative coolers at 45 to 618 kWh per year and A/C replacement savings at 80 to 571 kWh per year. Clearly, the current estimates are close to the bottom of this range. However, given the results of the on-site survey, the current estimate of 161 kWh seems to be within a reasonable range.

[77] *Op. cit.,* Blasnik, 2004.

8.7.7 Heating and DHW System Repair and Replacement

The savings for heating system repair and replacement were estimated from the gas model, combined into one estimator. These savings were sufficiently small to make it unfeasible to try to parse them out into finer segments. The average savings for the heating system repair and replace from the regression model are 8 therms per year. The previous LIEE evaluations indicated savings ranged from 16 to 43 therms per year for furnace repair and 39 to 147 therms per year for furnace replacement.

It is difficult to explain a discrepancy of this magnitude. One component of the difference between the PY2005 results and the previous evaluations is the approach to the modeling. In the previous studies, as in the current one, only one heating-related measure was identified for each home. This approach avoids collinearity in the measure specifications. In the 2000 and 2001 studies, if a home had a heating system replacement, the savings would be estimated for that measure alone, even if other measures were installed. Thus, the heating system savings may well include savings from attic insulation.

In the PY2005 model, attic insulation was assumed to be the measure with the largest potential impact, and therefore was identified as the primary heating measure. Heating system measures were second, and the smaller air sealing and minor envelope repair measures were marked only for homes without attic insulation and heating system repairs or replacements. An early model was tried with the heating system repair/replacement assumed to be the primary heating measure, and it was clear from the output that the estimator was picking up the attic insulation savings. (This method explained in more detail in Chapter 7, Section 7.6.2.)

The DHW repair/replacement is estimated to save about 12 therms per year, based on the regression results. Measure savings were estimated to be 10 to 19 therms in the 2001 LIEE evaluation and 18 therms in the PY02 evaluation. This measure in infrequently installed, and does not make a large contribution to program savings. The PY05 estimate is on the low side, but still within a reasonable range.

The low savings from the regression model is consistent with the on-site survey results suggesting that many LIEE participants use their heating systems little or not at all. The heating system and DHW repair/replacement savings from the regression model were used to estimate program savings in the absence of compelling information to suggest that they are understated.

8.8 Potential Savings from Water Reduction

8.8.1 Electric Savings to Water Utilities from Low Flow Devices

The reduced flow from the installation of showerheads has the added benefit of reducing the energy consumption required to treat, deliver and process wastewater. Electricity used to pump water in California accounts for 8% of the state's electric consumption[78] and water districts are the largest user of electricity in the state. Every saved gallon of water will also save the electricity used for pumping the water and processing the wastewater. The low flow showerheads installed through the LIEE program should result in a substantial reduction in water use, and it may be worthwhile to consider whether the larger savings to the water districts should be included in the cost effectiveness test.

Using the proxy values developed by the California Energy Commission's Public Interest Energy Research Program (PIER), we were able to calculate energy savings attributable to the reduced water consumption from the low flow showerheads.[79] For this analysis, we used the gallons per day savings developed from the showerhead testing and on-site information. Our calculations assume an in-service rate of 80% and a per showerhead reduction of water use of 5.5 gallons a day. The proxies provided by the PIER study are 5,411 kWh per million gallons of water for northern California and 13,022 kWh for southern California.

While calculating the additional energy savings is relatively straightforward, attributing them to a specific utility may be more complicated, as water is often moved long distances in California and the savings are likely to be distributed throughout the state. None the less, the savings are a valid program benefit that should be considered. The table below breaks the savings out between northern (PG&E) and southern (SCG, SCE, SDGE) California. The PIER study provides separate proxies for these two areas.

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[78] Water Supply Related Electricity Demand in California, Lon W. House, Ph.D. *Water and Energy Consulting*, December 2006 pg 2.
http://www.eere.energy.gov/state_energy_program/publications_by_topic.cfm/topic=409

[79] REFINING ESTIMATES OF WATERRELATED ENERGY USE IN CALIFORNIA, California Energy Commission, Public Interest Energy Research Program, Navigant Consulting, Inc., December 2006
CEC-500-2006-118

Table 8-19: Water System Electric Savings Attributable to Low-Flow Showerheads

	# of Showerheads	Gallons per Day per Showerhead	Gallons per Year per Showerhead	Total Gallons Water Saved per year	Annual kWh Savings Per Showerhead	Annual kWh Savings Total
Northern California (PGE)	50,807	4.4	1,606	81,596,042	8.7	441,516
Southern California	60,020	4.4	1,606	96,392,120	20.9	1,255,218
Total						1,696,734

8.9 Program Savings by Utility and Fuel Type

8.9.1 Electric Savings by Utility

Table 8-20: PG&E Electric Savings

		Measure Counts		Unit Savings		Total Program Savings		
		# of Households	# of Items Installed	Heating & Base Use (kWh)	Cooling (kWh)	Heating & Base Use (MWh)	Cooling (MWh)	Total (MWh)
Non-Weather Sensitive Measures								
Refrigerators	Multifamily	5,416	5,416	632		3,424		3,424
	Mobile Homes	2,907	2,910	826		2,402		2,402
	Single Family	15,820	15,824	795		12,571		12,571
Lighting (CFL's)	Multifamily	14,308	67,722	16		1,084		1,084
	Mobile Homes	5,241	25,646	16		410		410
	Single Family	33,456	181,982	16		2,912		2,912
Water Heating								
Conservation	Multifamily	1,120	3,698	240		269		269
	Mobile Homes	474	2,027	240		114		114
	Single Family	1,763	7,231	240		424		424
Weather Sensitive Measures								
Cooling	Multifamily	404	408		129		67	67
	Mobile Homes	170	179		179		23	23
	Single Family	1,908	2,003		163		359	359
Attic Insulation/Cooling	Multifamily	33	33		22		5	5
	Mobile Homes	0	0		22		0	0
	Single Family	972	972		22		21	21
Attic Insulation/Heating	Multifamily	4	2,189	198		9		9
	Mobile Homes	0	0					
	Single Family	167	169,103	247		41		41
Air Sealing/Envelope Repair	Multifamily	3,232	58,122	110		356		356
	Mobile Homes	538	13,563	192		104		104
	Single Family	2,233	226,131	160		357		357
Program Totals		56,942						24,951

Table 8-21: SCE Electric Savings

		Measure Counts		Unit Savings		Total Program Savings		
		# of Households	# of Items Installed	Heating & Base Use (kWh)	Cooling (kWh)	Heating & Base Use (MWh)	Cooling (MWh)	Total (MWh)
Non-Weather Sensitive Measures								
Refrigerators	Multifamily	4,536	4,536	632		2,868		2,868
	Mobile Homes	2,047	2,047	826		1,691		1,691
	Single Family	12,488	12,488	795		9,923		9,923
Lighting (CFL's)	Multifamily	8,355	38,783	16		621		621
	Mobile Homes	2,237	10,594	16		169		169
	Single Family	20,273	97,453	16		1,559		1,559
Water Heating								
Conservation	Multifamily	149	452	240		36		36
	Mobile Homes	7	21	240		2		2
	Single Family	82	237	240		20		20
Weather Sensitive Measures								
Cooling	Multifamily	42	42		129		5	5
	Mobile Homes	327	327		179		59	59
	Single Family	2,387	2,387		163		389	389
Attic Insulation	Multifamily	0						
	Mobile Homes	0						
	Single Family	3	3	247	22	1	0	1
Air Sealing/Envelope	Multifamily	712	712	110		78		78
	Mobile Homes	8	8	192		2		2
	Single Family	94	94	160		15		15
Program Totals		41,397						17,438

Table 8-22: SDG&E Electric Savings

		Measure Counts		Unit Savings		Total Program Savings		
		# of House holds	# of Items Installed	Heating & Base Use (kWh)	Cooling (kWh)	Heating & Base Use (MWh)	Cooling (MWh)	Total (MWh)
Non-Weather Sensitive Measures								
Refrigerators	Multifamily	1,484	1,484	632		938		938
	Mobile Homes	184	184	826		152		152
	Single Family	3,302	3,302	795		2,624		2,624
Lighting (CFL's)	Multifamily	4,232	17,834	16		285		285
	Mobile Homes	265	1,114	16		18		18
	Single Family	7,024	31,241	16		500		500
Water Heating								
Conservation	Multifamily	198	627	240		48		48
	Mobile Homes	41	153	240		10		10
	Single Family	227	824	240		55		55
Weather Sensitive Measures								
Cooling	Multifamily				129		0	0
	Mobile Homes	9	9		179		1	1
	Single Family	2	2		163		0	0
Attic Insulation/Cooling	Multifamily							
	Mobile Homes							
	Single Family	39	39		22		1	1
Attic Insulation/Heating	Multifamily							
	Mobile Homes							
	Single Family	1	1	247		0		0
Air Sealing/Envelope Repair	Multifamily	510	510	110		56		56
	Mobile Homes	1	1	192		0		0
	Single Family	178	178	160		28		28
Program Totals		13,553						4,717

8.9.2 Gas Savings by Utility

Table 8-23: PGE Gas Savings

		Measure Counts		Unit Savings	Total Program Savings	
		# of Households	# of Items Installed	Heating & Base Use (Therms)	Heating & Base Use (Therms)	Total (Therms)
Non-Weather Sensitive Measures						
Water Heating						
Conservation	Multifamily	12,106	35,390	8.2	99,269	99,269
	Mobile Homes	4,054	13,541	8.2	33,243	33,243
	Single Family	28,348	101,107	8.2	232,454	232,454
Repair/Replace	Multifamily	51	51	11.7	597	597
	Mobile Homes	0	0	11.7	0	0
	Single Family	1,334	1,334	11.7	15,608	15,608
Weather Sensitive Measures						
Attic Insulation	Multifamily	66	66	39.4	2,602	2,602
	Mobile Homes	0	0	0.0		
	Single Family	2,898	2,898	75.6	218,993	218,993
Air Sealing/Envelope	Multifamily	9,152	9,152	5.6	50,882	50,882
	Mobile Homes	3,687	3,687	21.3	78,383	78,383
	Single Family	23,234	23,234	15.8	366,968	366,968
Heating System Repair/Replace	Multifamily	7	7	9.5	66	66
	Mobile Homes	119	119	16.0	1,901	1,901
	Single Family	1,084	1,084	15.1	16,421	16,421
Program Totals		54,748				1,117,387

Table 8-24: SoCalGas Gas Savings

		Measure Counts		Unit Savings	Total Program Savings	
		# of Households	# of Items	Heating & Base Use (Therms)	Heating & Base Use (Therms)	Total (Therms)
Non-Weather Sensitive Measures						
Water Heating						
Conservation	Multifamily	16,452	47,144	8.2	134,906	134,906
	Mobile Homes	2,996	10,236	8.2	24,567	24,567
	Single Family	20,630	70,249	8.2	169,166	169,166
Repair/Replace	Multifamily	16	16	11.7	187	187
	Mobile Homes	48	98	11.7	562	562
	Single Family	877	882	11.7	10,261	10,261
Weather Sensitive Measures						
Attic Insulation	Multifamily	447	447	30.7	13,704	13,704
	Mobile Homes	0	0		0	0
	Single Family	1,174	1,174	51.6	60,558	60,558
Air Sealing/Envelope	Multifamily	16,533	16,533	4.4	72,243	72,243
	Mobile Homes	2,985	2,985	16.7	49,876	49,876
	Single Family	20,749	20,749	12.4	257,573	257,573
Heating System Repair/Replace	Multifamily	198	198	5.2	1,039	1,039
	Mobile Homes	265	265	9.1	2,406	2,406
	Single Family	6,016	6,016	7.7	46,418	46,418
Program Totals		41,535				843,468

Table 8-25: SDG&E Gas Savings

		Measure Counts		Unit Savings	Total Program Savings	
		# of Households	# of Items Installed	Heating & Base Use (Therms)	Heating & Base Use (Therms)	Total (Therms)
Non-Weather Sensitive Measures						
Water Heating						
Conservation	Multifamily	2,297	7,317	8.2	18,835	18,835
	Mobile Homes	137	522	8.2	1,123	1,123
	Single Family	5,743	21,780	8.2	47,093	47,093
Repair/Replace	Multifamily	0	0	11.7	0	0
	Mobile Homes	1	1	11.7	12	12
	Single Family	0	0	11.7	0	0
Weather Sensitive Measures						
Attic Insulation	Multifamily	2	2	9.6	19	19
	Mobile Homes	0	0	0.0	0	0
	Single Family	403	403	27.4	11,028	11,028
Air Sealing/Envelope	Multifamily	2,410	2,410	3.9	9,510	9,510
	Mobile Homes	180	180	15.1	2,716	2,716
	Single Family	5,601	5,601	11.2	62,789	62,789
Repair/Replace	Multifamily	23	23	1.7	39	39
	Mobile Homes	35	35	7.4	259	259
	Single Family	604	604	4.9	2,963	2,963
Program Totals		11,394				156,387

9 Conclusions and Recommendations

In the 2002 LIEE impact evaluation, the overall savings and some of the measure-specific savings were quite low in comparison to other research on residential savings. At that time a billing analysis was selected as the sole method used for estimating savings due to time and data constraints. In particular, savings from heating and cooling measures were difficult to estimate and the savings for CFL bulbs and DHW conservation devices were substantially lower than found in other research. However, the downside of this approach was that only external studies regarding general energy use during the period were available to try to interpret the low savings estimates stemming from the billing analysis.

Given this background, the 2005 evaluation was designed to tap information from numerous sources to inform and explain the results of the billing analysis. Another improvement in the PY2005 study was the application of the information-theoretic approach to model selection to employ an objective basis for choosing one model among others and to ensure that the regression analysis would not be results-oriented. In addition to these components of the study, the billing and program-level data were analyzed to provide a profile of the population and an overall assessment of the issues that could affect the LIEE program savings.

In total, these analyses indicate that LIEE participants tend to be low users and have fewer high-use electric equipment than the population as a whole. This characteristic of the population places a limiting factor on the total savings that can be achieved. While the per home savings estimates of 421 kWh per year for electricity and 20 therms for gas may seem small in comparison to other residential programs, they represent a reduction of 8% of electric use and 5% of gas use. Given the lower use of the population, these program savings are reasonable.

9.1 Recommendations

The recommendations discussed below are divided into five categories: reliability of savings, non-energy benefits, possible additional sources of savings for the LIEE program, data collection issues and suggestions related to program implementation.

9.1.1 Reliability of Savings and Considerations for Future Evaluations

The PY2005 evaluation was based on a billing analysis and informed by a number of other evaluation activities, including benchtesting of showerhead flow rates and an on-site survey of participants. The strategy allowed for internal and external validation of the measure and program savings. Even using this multi-faceted approach, the reliability of the savings varies at the measure level and housing type level, but the overall household savings are consistent with previous evaluations, the characteristics of the population and the features of the LIEE program as implemented.

The question remains whether the reliability of the savings could be improved. While it may be possible to improve the reliability, alternative strategies are likely to be significantly more expensive to implement, may not produce substantially different program-level savings and are not guaranteed to yield more reliable results. Consequently, pursuing other avenues, such as estimating non-energy benefits, may produce more useful results than incremental improvements to the reliability of the energy savings.

9.1.2 Non-Energy Benefits

It may be more fruitful to spend evaluation dollars investigating the potential non-energy benefits accruing from the program, such as comfort, water savings, moving funds from paying utility bills to other critical goods and services, and arrearage reductions. Recent research in this area has introduced some innovative approaches that may be worth pursuing, such as conjoint analysis.

It is entirely possible that the non-energy benefits associated with this program are substantial and could be underestimated in the current cost-effectiveness model. Also, program implementation may be further oriented toward achieving non-energy benefits, such as water savings. Pursuing these savings is likely to be more productive than continuing to try to make incremental improvements to the estimates of energy savings.

9.1.3 Additional Sources of Savings

A couple of opportunities for attributing additional savings to the program have come to our attention: water pumping, the retrofit of older washing machines, and cooling savings from attic insulation for SCE.

There are substantial potential savings from reducing water pumping use through low flow showerheads or other water-savings devices, as discussed in Chapter 8, Section 8.8. While these savings reflect a direct reduction in electricity use, they are not clearly associated with a specific utility. Our initial review suggests that up to 1.7 GWh could be added to the program savings, which would increase the total program savings by 4%. The issue becomes how to assign these savings to each utility.

The replacement of older, standard washing machines with horizontal axis models will substantially reduce total water use as well as water heating consumption for those participants who wash with warm or hot water. The combined water and energy savings could make such a retrofit cost effective. Many sources are available to estimate the savings from this measure, including the DEER database and Efficiency Vermont's reference manual. In addition, there are the potential savings associated with reducing water pumping use.

The analysis is likely to be underestimating the savings that occur when gas heated homes in the joint SCE/SoCal Gas area receive attic insulation. Because SoCal Gas does these jobs, there is not always a clear designation that the home has air conditioning and is served by SCE. The electric model showed small but significant cooling savings associated with homes that received attic insulation. However, these savings could only be identified in SCE homes with electric space heating and attic insulation, although SoCalGas may well have installed attic insulation in a number of the SCE homes. This situation could be alleviated by setting up a system to match joint SCE/SoCalGas participants in the program-level data sets.

9.1.4 Data Collection Issues

The utilities made substantial improvements during PY2005 in collecting the program-level data needed for evaluation. The most critical data fields are now being populated and are available for evaluation purposes. A few incremental improvements could still be made, as discussed below:

- Error-checking for some of the data fields could be improved, in particular SCE's house type field and SoCalGas's space and water fuel types and measure descriptions for heating system repairs and replacements.
- SoCalGas could establish a system to assign a single unique household identifier regardless of the combination of measures installed at the site.
- The utilities should track, either at the program- or measure-level, whether an evaporative cooler is a new installation or a replacement.
- SCE and SoCalGas should consider whether there is a mechanism to facilitate the matching of joint SCE/SoCalGas customers to allow the estimation of cooling savings for all homes that receive attic insulation.
- The utilities should investigate how to obtain information about LIHEAP installations in LIEE homes. This should be possible especially when the same contractor performs both LIEE and LIHEAP services.

These data enhancements would improve the next impact evaluation and should allow the estimation of additional and legitimate program savings.

9.1.5 Program Implementation Issues

Although this study was primarily an impact evaluation, a few issues arose that may be useful for improving program implementation. Some of the findings that may be relevant for program implementation are listed below.

- The energy education component of the study found some conservation actions with high potential savings, such as pulling down shades to reduce cooling use, had a low overall incidence and high attribution rate to LIEE, suggesting that focusing on recommendations with higher savings and lower acceptance may improve the impacts of this program component.
- About 35% of the LIEE-installed CFLs failed, had been removed or were never installed. This low persistence rate of the CFLs is a matter of concern, as well as 8% of program participants who responded that the CFLs were not actually installed. Improving the quality of the CFL lamps and ensuring their installation are small steps that could help boost program savings.
- The retention rate for showerheads and aerators was 80%, leaving substantial room for improvement.
- About 35% of the homes with LIEE evaporative coolers report that they do not always have a window open when the unit is operating, suggesting that education about the proper use of the cooling equipment is another worthwhile area to explore.

- Approximately 10% of LIEE household own a secondary refrigerator or freezer. Consequently, it may be worthwhile to incorporate information about the savings related to the retirement of secondary refrigerators into the energy education component and consider referring these participants to other utility or municipal efforts to collect secondary refrigeration equipment.
- The listed flow rate on the outside of the showerhead (when available) is not necessarily a good indicator of the fitting's flow rate, suggesting that identifying showerheads with a flow rate above 3.0 gpm is not a simple task.
- Some fittings are restricted by mineral deposits and others with signs of mineral deposits have been modified to allow for increased flow.
- The flow rates for the replacement, low flow showerheads are more variable than would be expected.

While not a primary objective of this study, these findings may provide useful feedback to program implementers.

9.2 Final Comments

The objective of this study was to improve the reliability of the LIEE program savings estimates by triangulation and improved modeling methods. This strategy produced some fascinating synergies and allowed us to place our results in a larger context. While the modeling results exhibited variability as is often the case in residential billing analysis, the testing of the showerhead flow rates, on-site surveys and review of other residential studies allowed us to conduct both internal and external validation of the savings. This process has produced solid and defensible program savings