Impact Evaluation of the 2009 California Low-Income Energy Efficiency Program

Final Report

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ECONorthwest
ECONOMICS • FINANCE • PLANNING
222 SW Columbia St, Suite 1600
Portland, Oregon 97201
503-222-6060

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Executive Summary

This report presents impact evaluation results for the California Low Income Energy Efficiency Program[1] (LIEE) for program year 2009. The four investor-owned utilities—Southern California Edison (SCE), Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E), and Southern California Gas (SCG) commissioned the evaluation. The California Public Utilities Commission Energy Division also assisted in the commissioning and management of this evaluation.

The evaluation team was led by ECONorthwest, with extensive analytical and data collection assistance provided by West Hill Energy & Computing, Wirtshafter Associates, Michaels Engineering, Quantum Market Research, and John Stevenson from the University of Wisconsin Survey Research Center.

LIEE Program Delivery Overview

The LIEE program is operated by Southern California Edison (SCE), Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E) and Southern California Gas (SCG). 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.

For low-income households participating in the LIEE Program, an initial on-site energy assessment is conducted, followed by the installation of energy savings measures. 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.

Program delivery is a coordinated effort with the individual utilities working with community based organizations (CBOs) 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 CBOs and contractors. All service providers receive training through the utilities to ensure consistent service across the service territories.

Evaluation History

The impact evaluations for this program from 1998 through 2005 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 across impact evaluations, particularly at the measure level. In the 2002 LIEE impact evaluation[2], for example, 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.

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[1] The LIEE program is currently known as the Energy Savings Assistance Program.

[2] The results of the 2002 LIEE impact evaluation were not used for IOU reporting.

In response to these issues, the PY2005 evaluation followed a research plan that emphasized the collection of data from multiple sources and the option of calculating alternative savings estimates for some critical measures. This approach of devoting some of the data collection and analysis resources to refining estimates for selected measures was continued in the current PY2009 evaluation.

PY2009 EVALUATION OBJECTIVES

Research Objectives

The primary objectives of the PY2009 impact evaluation are listed below.

- Estimate first year gas and electric energy savings and coincident peak demand reduction
- Estimate savings in aggregate and also by measure and by housing type (multifamily, single family and mobile homes), where feasible
- Explore additional billing regression models and attempt to improve the savings estimates for certain key measures, including evaporative coolers, furnace repair, and furnace replacements.

Compliance with the California Evaluation Protocols

This study was designed to be consistent with the *California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals*, adopted by the CPUC on June 19, 2006. The estimates of gross demand savings meet the standard for basic rigor and the gross energy savings are consistent with the enhanced rigor criteria.[3] Adherence to the protocols is demonstrated by the characteristics of the analysis listed below.

- Energy savings are primarily based on a fixed effects regression model, with twelve months of pre- and post-installation billing data.
- A comparison group of PY2009 LIEE participants was selected and the impacts of incorporating this comparison group into the model were assessed.
- Factors that change over time (such as weather, changes to the home, behavior changes) were evaluated and included into the model as indicated.

Additional components of the study were designed to minimize the possibility of bias and ensure that the process and results are objective and defensible. For example, the information-theoretic approach to model selection (discussed in Chapter 4) was performed to ensure an objective process for choosing the final model. The study also included surveys of participants to allow for independent estimation of savings for a few key measures as well as qualitative analysis to inform and support the regression results from an entirely different perspective.

[3] The requirements for gross energy and demand savings are described in detail on pages 26 through 35 of the Protocols.

EVALUATION METHODS

Components of the Study

The 2009 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 impact evaluation consisted of three primary components:

- **Preliminary Research.** The preliminary research phase included a comprehensive review of research methods used for similar low-income programs and included the previous impact evaluation studies for the California LIEE Program. This preliminary research review combined with our team's assessment of alternative methods resulted in a detailed research plan, which was submitted to and approved by the utilities and the CPUC Energy Division.

- **Data Collection**. A significant amount of evaluation resources were used to collect primary data through participant phone surveys, non-participant phone surveys, and on-site audits of participating customers. These data were used to enhance the billing regression models and to provide additional context on how energy is used within low-income households targeted by the program.

- **Impact Estimation.** The selected research methods and the results of the data collection were combined to produce estimates of first-year electric and gas for the PY2009 LIEE measures.

We reviewed the recent impact evaluations in the preliminary research stage and developed our approach to build on the successful elements of these past studies. The ECONorthwest team considered a range of analysis options for evaluating the specific measures covered in the LIEE program. Ultimately, it became clear that a regression-based billing analysis was the only viable alternative given the characteristics of the program, available data, evaluation timeframe, and the budget.

Engineering and monitoring techniques were eliminated as options because they require access to detailed pre-installation data at each home. The time for pre-metering had already passed for PY2009 and developing alternative estimates for all LIEE measures would have been prohibitively expensive. The program as implemented is designed to ensure that all *feasible* measures are installed. Consequently, the program tracking data do not include sufficient detail regarding the pre-installation conditions of the home to apply engineering methods.

Estimating savings using simulations of whole building energy use was also considered and then eliminated as an option as it too was prohibitively expensive and not likely to produce superior results. With the simulation method, the underlying assumptions are typically so general that they do not relate to any specific building, and may not accurately depict the treated population of low-income households. Improving these estimates would have required detailed pre-installation baseline data. For engineering strategies, the baseline would have entailed a detailed description of the pre-installation conditions, such as the results of a blower door test (for infiltration measures), the quantity and condition of the pre-existing insulation, or the number of gallons per minutes used by the existing showerhead. For metering, the pre-installation baseline would be the metered amount of energy used by the equipment prior to the installation. Additionally, the opportunity for conducting pre-metering for 2009 LIEE participants was passed at the time of this evaluation.

For these reasons we used a billing regression to estimate impacts for the majority of measures covered in the PY2009 LIEE program.

Analytical Methods

The specific analysis steps followed in this evaluation are as follows:

1. Used a billing regression model and data from 2008 LIEE participants to estimate kWh and therm impacts for measures that are included in both the 2008 and 2009 LIEE programs.
2. Developed versions of the billing model that included a comparison group of non-participants in the sample. The comparison group allowed for the estimation of net impacts (if different from gross) and also incorporated broader market trends (e.g., fuel prices, recession, effect of other efficiency programs).
3. Conducted a phone survey of LIEE participants and eligible non-participants and used their survey results to supplement the billing regression model.
4. Conducted on-site inspections with LIEE participants to obtain additional information on selected measures (evaporative coolers, furnace replacement/repair) and how the installed measures are being used. On-site data were used in a separate regression for these customers in an attempt to further refine the impact estimates for the selected measures.
5. Regression-based billing analysis using customer-specific intercepts was performed to estimate savings at the measure and household level. These intercepts help control for unobserved variation across individual households within the model.
6. House-specific regression analysis of weather-dependent loads was conducted to develop factors to estimate heating and cooling savings for single family, multifamily and mobile homes.
7. Information-theoretic model selection allowed us to determine the best candidate model for estimating savings.
8. Comparison of billing analysis and survey results to previous LIEE evaluations was done to place savings estimates in context.
9. Coincident peak savings were estimated based on the KW/kWh factors from matching measures in the DEER database.

The combination of data from multiple sources turned out to be an invaluable asset in interpreting the results of the billing analysis and developing solid savings estimates. For example, the phone survey and on-site survey indicated that many LIEE participants use their heating systems rarely or not at all, which explains the low savings estimates for heating-related measures. This strategy of triangulation allowed us to conduct internal and external validation of the measure-level savings, resulting in solid and defensible program savings.

Reliability of the Results

Estimating reliable savings at the individual measure and household level are challenging under any circumstances. In this analysis, measures were grouped into larger categories as possible. Savings by housing type cannot be directly estimated from the model and the final savings were estimated using a variety methods depending upon the available information. These strategies accounted for the differences in consumption levels and weather conditions among the multifamily, mobile homes and single family homes.

Impact Results

Electric Savings

Total program energy savings by utility are summarized in Table S1 below. In aggregate, the LIEE PY2009 program activity reached 240,329 homes, savings 57.5 GWh, 12.7 MW and 1.6 million therms.

Table S1. PY2009 Total Program Savings

	# of Participants	Annual MWh	Coincident Peak (KW)	Annual Therms
PG&E	81,516	32,788	5,547	707,809
SCE	71,896	17,773	6,453	1
SDG&E	20,835	6,320	679	168,847
SCG	66,082	616	58	710,979
Totals	240,329	57,497	12,737	1,587,637

Table S2 shows the annual estimated household savings for the 2000, 2001, 2002, 2005 and 2009 evaluations, along with the annual energy consumption for the group of 2009 program participants used in the regression models, during the pre-installation period.

Table S2. Comparison of Household Savings, PY2000 to PY2009

	Average Annual Pre-Installation Energy Consumption[4]	PY2009 Evaluation	PY2005 Evaluation	PY2002 Evaluation	PY2001 Evaluation	PY2000 Evaluation
Electric Savings (kWh)						
Combined Utilities[5]	5,752	330	423	366	213	175
PG&E	5,933	402	433	399	236	240
SCE	5,819	247	435	286	203	153
SDG&E	4,580	303	342	370	215	89
Gas Savings (Therms)						
Combined Utilities	318	9	18	8	18	24
PG&E	331	9	19	9	18	28
SDG&E	260	8	14	4	13	13
SCG	317	11	17	17	20	26

Electric savings increased steadily from 175 kWh per year in PY2000 to 423 kWh in PY2005 before decreasing to 318 kWh in the PY2009. The current savings estimate represents a decrease of

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[4] This column reflects the average annualized pre-installation kWh consumption for 2008 participants who were included in the population regression sample.

[5] Combined utility average consumption were calculated from the data set used for the regression analyses. Household savings were derived by summing the savings separately for each of the four utilities and dividing by the total number of participants.

approximately 6% in electric consumption on average. The PY2009 electric savings are about 22% lower than they were in PY2005, with the largest decreasing occurring in SCE's service territory.

Table S3 present the electric savings by major measure group. This analysis shows that refrigerators and lighting measures combined account for almost 82% of the total program energy savings, and 53% of the estimated coincident peak reduction. Cooling, DHW, and air sealing/envelope measures make up the majority of the remaining savings.

Table S3. Electric Savings by Measure Group

End Use	Savings per Home (kWh)	Energy Savings (MWh)	% of Total	Coincident Peak Demand Savings (KW)	% of Total
Refrigerators	697	24,628	43%	4,187	34%
Lighting	346	22,226	39%	2,376	19%
HVAC (Cooling)	351	4,895	9%	5,747	46%
Hot Water Conservation	24	309	1%	52	0%
Air Sealing/Envelope	63	4,597	8%	0	0%
Totals		56,656		12,361	

Gas Savings

The gas savings are more variable from one year to the next. As shown in Table S2, the average household savings for the statewide program are 9 therms per year, or 3% of gas consumption on average. While this represents a household savings decrease of almost 50 percent from PY2005, as a share of consumption it is similar to PY2005, when therm savings were 4% of average household consumption.

Table S4 shows the gas savings by measure group. Hot water conservation and air sealing/envelope measures have low household savings and high penetration, and in combination account for almost 95% of the total program savings. Although the current evaluation did not find savings for the hot water and heating replace/repair measures, the level of participation in these areas comprised a smaller share of total participation at approximately 38 percent of households receiving gas measures.

Table S4. Gas Savings by Measure Group

	# of Households	Savings per Home (Therms)	Total Program Savings (Therms)	% of Program Savings
Hot Water Conservation	133,397	7	956,274	61%
Air Sealing/Envelope	131,028	4	529,454	34%
Attic Insulation	8,010	10	83,572	5%
Hot Water Repair/Replace	4,704	0	0	0%
Heating System Repair/Replace	32,984	0	0	0%

Impact Results Discussion

Comments on a draft version of this report have focused on a desire to explain why the results in the current evaluation are different from the last impact evaluation in 2005. One must not conclude from these differences across time that one set of estimates is 'correct' or 'more accurate' than the other; the estimates may be equally accurate but reflecting different market conditions inherent in two different evaluation periods (e.g., changing weather conditions and/or the current recession versus the more robust economic conditions in 2005, for example).

Table S5 and Table S6 compare the results of the current evaluation with the 2005 impact evaluation and earlier evaluations. While the current estimates are different from 2005, they are generally within the historical range from previous evaluations. As this comparison indicates, there is significant variation across data sources and evaluation years in the impact estimates. While some of this difference may be attributable to differences in impact estimation methods, there are also differences in underlying program and market conditions that contribute to the variation, including changes in the economy, weather, program implementation, customer attitudes toward energy efficiency, and the cumulative effect of efficiency programs in California over time.

Table S5. Comparison of Electric Impacts with Previous Evaluations

End Use	2009 Evaluation (kWh)	2005 Evaluation (kWh)	Previous LIEE Evaluations (kWh)
CFL	16	11	22-43
Refrigerator	711	755	645-795
Attic Insulation (Cooling)	103	257	44-208
Attic Insulation (Heating)	0	70	35-288
Evaporative Cooler	504	245	98-571

Table S6. Comparison of Gas Impacts with Previous Evaluations

End Use	2009 Evaluation (therms)	2005 Evaluation (therms)	Previous LIEE Evaluations (therms)
Hot Water Conservation	7.5	13.5	10-20
Air Sealing/Envelope	4.6	6.1	3-11
Attic Insulation	10.1	47.2	10-59
Hot Water Repair/Replace	0	12.1	9-19
Heating System Repair/Replace	0	2.4	0-147

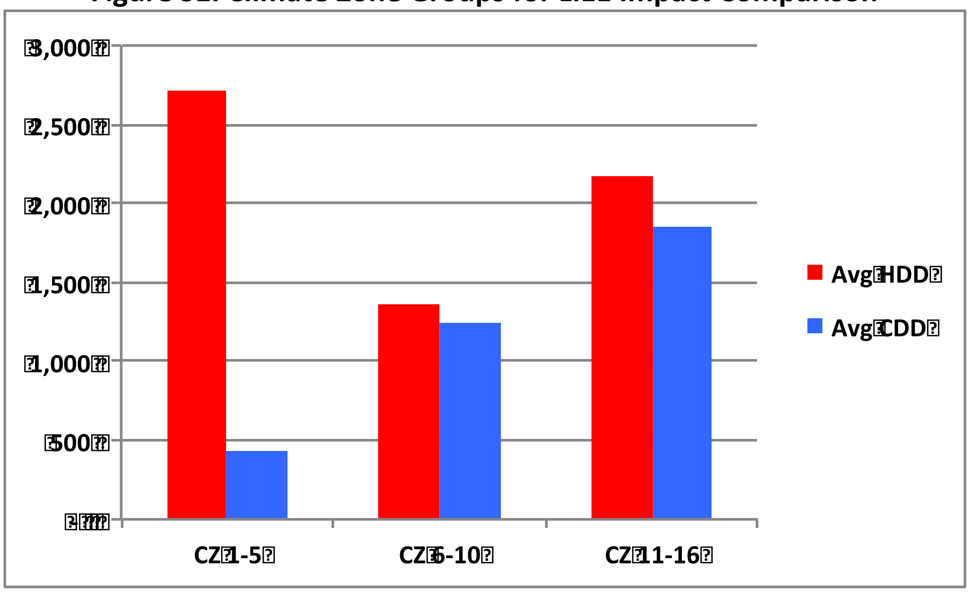
In an attempt to shed some light on the differences between the current impact evaluation and the 2005 impact evaluation, we examined in more detail the shifts in participation by climate zone for weather-dependent gas measures. We limited our focus on those measures that had low (or zero) impacts in the current evaluation relative to the 2005 evaluation.

A possible explanation for the lower impact estimates for weather-dependent measures is that participation has shifted toward milder climate zones (or that weather conditions were milder in the

2009 evaluation relative to the 2005 analysis). For weather-dependent measures such as furnace replacement/repair and insulation, for example, a relative increase in participation in milder climates would reduce the average impact as heating loads would be reduced.

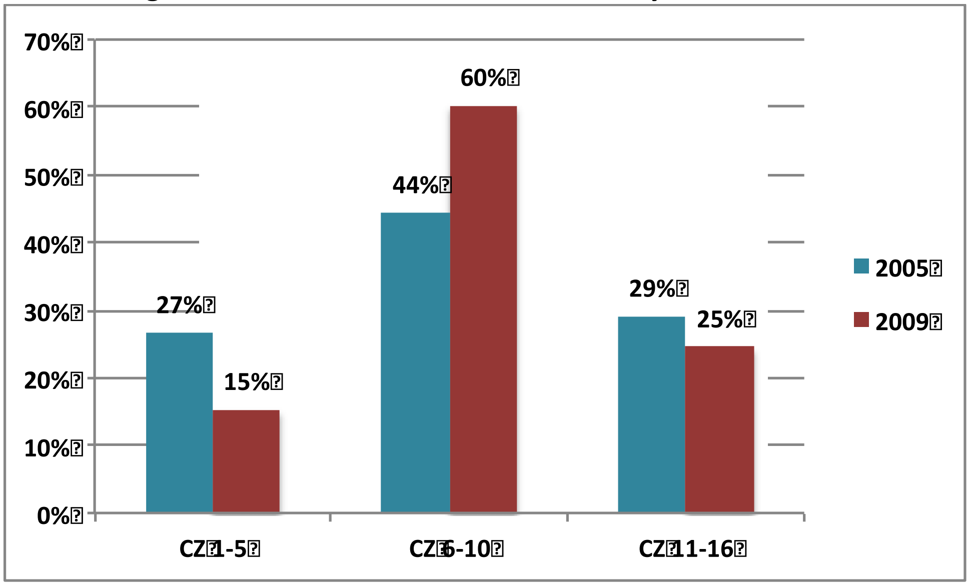
Figure S1 shows the HDD and CDD for the 16 climate zones used in the 2009 impact evaluation, with zones aggregated into three groups; climate zone 1-5 (group 1), climate 6-10 (group 2), and climate zones 11-16 (group 3). As can clearly be seen from Figure 6, the middle climate zone group (climate zones 6-10) has milder temperatures for heating. Consequently, we would expect lower impact estimates for weather-dependent heating measures installed in these zones relative to the other areas (all else equal).

Figure S1. Climate Zone Groups for LIEE Impact Comparison



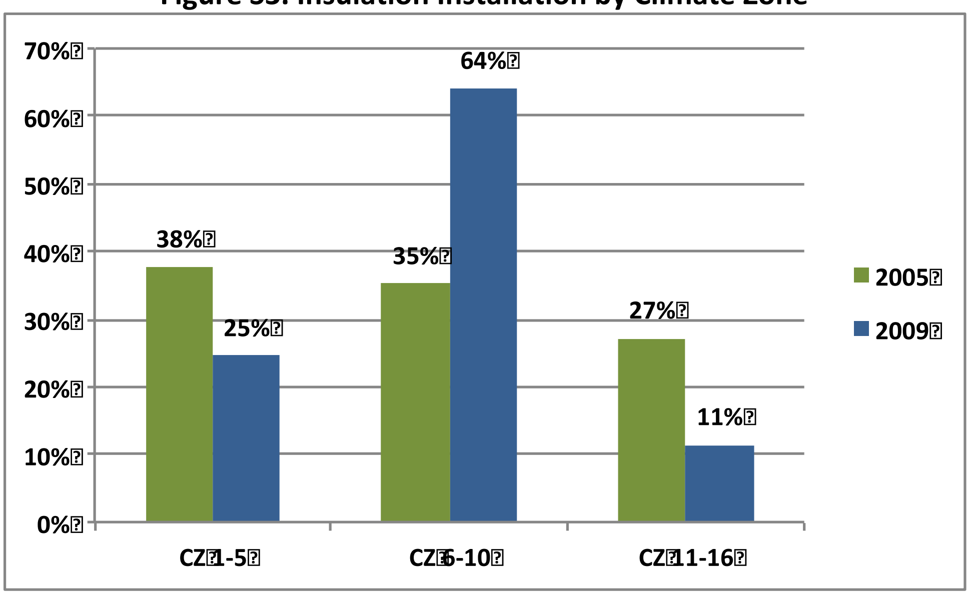
The next step is to compare the distribution of installations in these climate zone groups for those weather-dependent measures with very low or zero estimated impact in the current evaluation. Figure S2 shows the comparison of installations for the weatherization measure group. There is a pronounced shift of the installation of these measures from the more extreme climate zones 1-5 to the milder areas of climate zone 6-10. In the 2009 impact evaluation, the installation of weatherization measures in the milder zones increased from 44 to 60 relative to the 2005 evaluation. This was primarily due to fewer installations in the more extreme climate zones 1-5, which decreased from 27 percent in 2005 to 15 percent in 2009.

Figure S2. Weatherization Installation by Climate Zone



A similar shift to milder climate zones is also apparent for the gas insulation measures, as shown in Figure S3. In this case, the shift to the milder climates zones is even more pronounced. In the colder climate zones 1-5, weatherization installations decreased from 38 to 25 from 2005 to 2009.[6] This corresponded to an increase in installations in the milder climates zones 6-10, which saw its share almost double from 35 percent in 2005 to 64 percent in 2009.

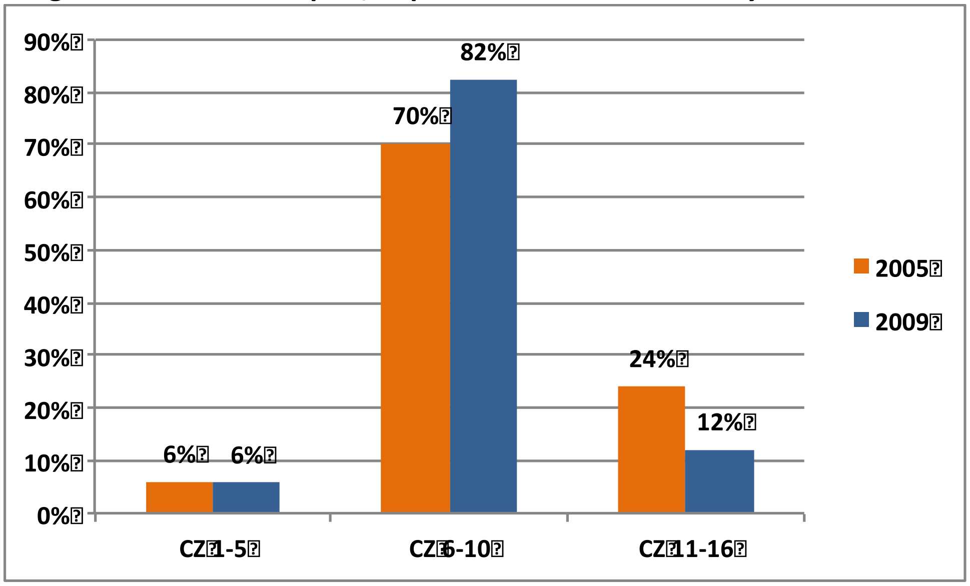
Figure S3. Insulation Installation by Climate Zone



[6] Note that in the climate comparison charts, 2009 refers to the impact evaluation year. The data used to create these charts are actually from 2008 participants, to be consistent with the other data used to estimate the regression model.

Finally, the comparison of furnace repair and replacement by climate zone is shown in Figure S4. Here the shift to milder climates zones is less pronounced, with an increase from 70 to 82 percent in the share of installations in the milder climate zones 6-10. As discussed below, however, there are additional shifts in climate zones among customer user categories that provide information on the lower impact estimates for the furnace repair/replacement measure group.

Figure S4. Furnace Repair/Replacement Installations by Climate Zone



The preceding figures suggest that at least part of the decrease in impact estimates relative to 2005 can be explained by a shift in participation to milder climate zones for the weather-dependent gas measures.

Some additional analysis was done to see how changes in weather across different categories of energy usage groups might be affecting the impact estimates. In the population billing regression for both 2005 and 2009, the model divides participants into four use levels (based on consumption) and consumption was incorporated separately as an interactive term so that impact estimates are in part a function of kWh or therms consumed. As a result of this specification, we would generally expect that impacts would increase with overall usage for weather-dependent measures (other things equal). This was generally the case in 2005, but as demonstrated in the following tables, a significant drop in HDD from 2005 for the highest usage groups is contributing to the lower overall impact estimates for these measures.

Table S7 shows this comparison for the furnace repair/replacement measure group. Note that here and throughout the report, savings are indicated with a *positive* number. In cases, where a negative impact is estimated (i.e., the model estimates an *increase* in usage for that measure), the impact value is set to zero.

For the higher usage groups (Use Level 3 and 4) that had the furnace repair/replacement measure, the average number of heating degree days dropped substantially for both the higher use groups (highlighted in yellow). Since the impact estimates are calculated using heating degree days, the decrease in HDD led to a corresponding drop in the impact estimates for these two groups. Since the impact estimate is negative in 2009 for all four use levels, the final impact estimate was set to zero.[7]

Table S7. Furnace Repair/Replace Impact Comparison by Usage and Weather

Use Level	Average Annual HDD		% Change	Savings (therms/yr)	
	2005	2009		2005	2009
1	1,775	1,738	-2%	-13.8	-65.0
2	1,827	1,674	-8%	-15.9	-35.5
3	1,895	1,437	-24%	11.0	-21.8
4	2,014	1,249	-38%	38.2	-7.2

A similar result was found for the insulation measures when changes in HDD are compared for the individual use level groups. The comparison of therm impacts and HDD are shown in Table S8 for both the 2005 and 2009 evaluations. For both the higher use categories, HDD decreased significantly between the two analysis periods. This resulted in a significant decrease in the impact estimates for insulation in 2009, as highlighted below in the last two rows of Table 80.

Table S8. Insulation Impact Comparison by Usage and Weather

Use Level	Average Annual HDD		% Change	Savings (therms/yr)	
	2005	2009		2005	2009
1	1,688	1,881	11%	-1.3	-8.8
2	1,925	1,923	0%	8.9	-0.3
3	2,120	1,646	-22%	48.1	16.1
4	2,231	1,260	-44%	90.8	12.8

The preceding analysis suggests that much of the change in impact estimates for weather-dependent measures can likely be attributed to a shift in participation to milder climates and/or milder weather conditions relative to the 2005 impact analysis.

Conclusions and Recommendations

Full Model Results

This evaluation of the California Low-Income Energy Efficiency Program builds upon previous evaluations. Like earlier studies, the estimates of energy savings from the installed program are

[7] As discussed in the survey section of this report, both the phone survey and on-site respondents indicated that a significant number of the furnace repairs and replacements occurred on furnaces that were not working prior to the program intervention. A significant number of respondents also indicated that they use their heating system more since participating in the program. Given this information, it is not surprising that the billing regression model returned a negative impact estimate as many of these customers are actually increasing their furnace use after participating in the program.

obtained using a fixed effects regression model analyzing the full population of participants with usable billing records.

Table S9 shows a comparison of average household savings estimates from the PY2009 and previous impact evaluations. In general, the impact estimates from the PY2009 are lower than those found in the PY2005 evaluation, even though the same general method for estimating savings and choosing a final model was used in both evaluations (and conducted by several of the same researchers). The current impact estimates are within the range found in previous studies, however.

Table S9. Summary Savings Estimates (Average Annual Savings Per Household)

	Average Annual Pre-Installation Energy Consumption[8]	PY2009 Evaluation	PY2005 Evaluation	PY2002 Evaluation	PY2001 Evaluation	PY2000 Evaluation
Electric Savings (kWh)						
Combined Utilities[9]	5,752	330	423	366	213	175
PG&E	5,933	402	433	399	236	240
SCE	5,819	247	435	286	203	153
SDG&E	4,580	303	342	370	215	89
Gas Savings (Therms)						
Combined Utilities	318	9	18	8	18	24
PG&E	331	9	19	9	18	28
SDG&E	260	8	14	4	13	13
SCG	317	11	17	17	20	26

The lower savings relative to 2005 may be a reflection of the inherent difficulty in estimating savings from a billing regression models for residences where expected savings values are a small fraction of total energy use and where there can be substantial variation across households and program years (such as economic conditions) that cannot be entirely controlled for in the model. Additionally, some of the lower impact estimates may be a sign of diminishing savings available. Program savings may be less because the most opportune homes have already been treated and households have over the years adopted some of the measures, such as CFLs, previously supplied.

A change in weather conditions relative to 2005 is a third possible explanation of the lower impact estimates. A closer examination of the weather conditions in the current evaluation indicates that a shift in participation to milder climate conditions may explain at least some of the decrease in estimated savings relative to the 2005 impact evaluation. This was evidenced by a substantial shift in participation to milder climate zones for some weather-dependent measures as well as lower HDDs experienced in the current evaluation for some high usage customers installing these measures.

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[8] This column reflects the average annualized pre-installation kWh consumption for the 2008 participants who were included in the population regression analysis sample.

[9] Combined utility average consumption were calculated from the data set used for the regression analyses. Household savings were derived by summing the savings separately for each of the four utilities and dividing by the total number of participants.

While LIEE participants tend to use less energy than the average residential utility customer[10], this analysis clearly demonstrates that there are some high users among LIEE participant and the savings in these homes can be substantial, especially when these homes are located in the more extreme climate areas. This finding applies to some potentially marginal measures including evaporative coolers and heating system repair and replacement, as well as more common and stable measures such as refrigerator replacement.

It is also clear from the estimation of savings by climate zone that savings are considerable in the more extreme climates. The wide geographic range of the CEC climate zones evens out local variations in temperatures, and it is highly likely that homes in some areas in climate zones 10 and 15 may well have higher or lower savings. Specifying homes eligible for specific weather-sensitive measures based on CEC climate zone may eliminate some participants with potentially cost effective installations.

We have generated two gas models, one that specifically identifies takeback effects and one that does not.[11] The results identify that some takeback effect is occurring, i.e., that participants are using their heating equipment more now that it is more efficient. We are presenting our overall results without the takeback effects because these results are more comparable to previous evaluation results that only identified energy savings.

Recent articles about takeback have suggested that the issue is so large as to completely negate the value of the efficiency efforts. That is certainly not evidenced in these results, though takeback is substantial. It has always been accepted that a certain amount of takeback would happen, especially when treating low-income households. The higher than normal takeback effect happens here because households are using very little or no gas for heating in the pre-treatment period. The LIEE upgrades allow participants to increase heating use by making equipment more efficient, and in some cases fixing equipment that was not previously used. In some cases, this increase is accompanied by a decrease in supplemental heating using wood or electric heaters and ovens. This analysis does not fully track all of these trade-offs and their ultimate effects on carbon emissions or in overall health and safety benefits. These takeback and other non-energy benefits may be sufficient to justify continuation of some measures that fail a strict energy-only cost effectiveness test.

Phone and On-site Heating and Cooling Models

This study was designed to try to explain the magnitude of the savings amounts for major heating and cooling measures. Previous impact evaluations found smaller impacts for major heating- and cooling-related measures than expected, especially for natural gas measures. Because these measures represent a substantial portion of LIEE expenditures, the 2009 LIEE evaluation included several enhancements over earlier LIEE evaluations, such as focusing on building more complete models of the heating and cooling use and savings in treated homes. These enhancements involved both broader data collection and analysis. The data collection efforts added additional questions on heating and cooling use in the

[10] For a discussion of the average energy usage for low-income customers and a comparison with the average for California residents, see pp. 42-45 of the 2005 evaluation report *Impact Evaluation 2005 California Low Income Energy Efficiency Program Final Report* (August 19, 2008).

[11] It was not possible to implement the same strategy for the electric model due to the relatively small percentage of the LIEE population who received electric heating- or cooling-related measures.

telephone and on-site survey and detailed examination of the home characteristics and heating and cooling system components in the on-site survey.

The data collection phase of this study included a phone survey of 1,500 participants and an on-site assessment of 400 participant households. In addition, this study also added a phone survey of 1,500 non-participant households. The phone surveys included a battery of questions on household demographics, energy use, influence of the education session, and program satisfaction similar to those used in previous years. This year's surveys also added an extensive battery on the detailed use of heating and cooling equipment before and after LIEE interaction.

The on-site data collection done as part of the 2005 evaluation was focused on measuring savings from water heating conservation and lighting education measures. That collection instrument included measurement of showerhead flow rates and lighting that we did was not included in this year's collection. Instead, the auditors collected measurement of square footage of windows, walls, floor area, and attic areas. The auditor also collected detailed information on all heating and cooling equipment. Finally, the auditor asked detailed questions on equipment use and occupancy changes.

The real achievement of this round of modeling is the inclusion of some of the behavior elements in the phone and on-site analyses that helped corroborate the findings from the population billing regression. Data regarding prior use of heating equipment is a telling factor in explaining energy savings. Interestingly, data on the physical characteristics of the homes did not prove to be as useful in defining energy savings. Given that the most useful questions were behavioral in nature, it does not appear as though on-site assessments will be required to duplicate the results should this type of study be desired in the future.

The inclusion of use variables helps explain why the full model results are not showing any measureable savings for furnace repairs and replacements. The primary explanation for why there was no measurable savings from furnace repairs and replacements is that most homes use very little heating. This is supported by the results of the phone and telephone survey. In general, homes that received a furnace repair or replacement increased their household use after the treatment. For the majority of households, the use of heating is small and the other measures such as insulation resulted in little or no energy savings.

The phone and on-site survey results also show that the program education is having only a small effect on participants, with only 30 percent of on-site survey respondents continuing to follow through with recommendations received during the LIEE visit. This result is consistent with the findings of the PY2005 evaluation.

RECOMMENDATIONS

The full data population model represents the best estimate of measure savings. The question arises as to which of the model using the on-sites sample, telephone sample, or full population supplies the best estimate of measure savings. From our perspective, the full population model is the best estimate of measure saving because it alone includes a full set of participants and reflects overall savings. The smaller models (because they have additional behavioral and house characteristic data) often help explain why some savings estimates are what they are. For example the on-site model indicated that previous use of heaters and changes in heater use were major factors in explaining the savings estimates from the full population model. While we did not have the detailed information about previous use, we were able to restructure the full data model to define usage categories that proved to be an effective means of including previous use as a factor in the final model.

Using the 2008 participants to estimate impacts for PY2009 was also useful in that it allowed the evaluation to proceed without waiting for a full year of post-installation data for 2009 participants. In the future, we recommend that this approach be adopted, as long as the years covered are reasonably similar with no substantial differences in economic conditions and/or program delivery.

Surveys and on-sites are useful, but their cost limits their applicability. This evaluation included the most extensive data collection and modeling effort to date in an effort to quantify program impacts from a variety of sources. While this effort yielded useful information, the on-site and phone survey regressions ultimately did not improve upon the prior method of using the full LIEE participant dataset to estimate impacts. As the phone survey and on-site surveys are both time and budget intensive, future evaluators should think twice before using them as a primary means to develop billing regression models with the expectation that they will improve upon the population regression model.

Although we could not improve upon the population regression model, the phone and on-site data did help confirm findings from the regression models. Data from the on-site survey results that confirm that treated households do not all behave as expected from engineering assumptions. Some households were found to not heat or cool when or as often as expected. Others were found to increase usage after the new equipment is installed often because the systems were not previously used and were subsequently used more after repair or replacement. As it turned out, the physical measurements collected by the on-site auditors proved to be less useful than the behavioral related questions collected by both the phone and on-site surveys. If another round of detailed analysis is attempted, it will be possible to use the phone survey to collect the battery of behavioral questions. This would eliminate the need for on-sites altogether.

Continue targeting evaporative coolers in the hottest climates and consider additional education. Savings for evaporative coolers could be improved through additional education. The phone and on-site survey respondents indicated that many of them did not realize that the evaporative coolers should be operated with the windows open and that they should not run their air conditioners as the same time. Some participants are also still continuing to use their existing cooling systems in addition to the evaporative cooler. Better education on proper use of the evaporative cooler should increase savings for these customers.

Program should restrict furnace repairs and replacements to households with large weather dependent loads. The program already targets the hottest areas for installing evaporative coolers. A similar strategy needs to be adopted for furnace repair/replacements. While any cooling application is likely to have peak summer demand benefits even if there are few kWh's saved, there is no equivalent benefit in treating homes that use small amounts gas for heating. The low estimates for gas heating savings from the population regression model is consistent with information from both surveys and the PY2005 evaluation. Participants receiving a furnace replacement or repair indicate that they use the new system more often than before. There is also evidence that there are supplemental heating systems used, which would further erode savings from this measure. Consequently, it is not surprising that these customers use their heating systems more after participating, which was reflected in the billing regression model for these measures. The on-site results also provided additional insights into how heating and cooling equipment are being used, such as limited cooling equipment use in some areas with milder climates and manual control of these systems when they are used. These behavioral findings help support some of the lower impacts estimated for these measures from the billing regression.

Targeting more extreme climate zones will increase savings for weather-dependent measures. While this is a somewhat obvious recommendation, a pronounced shift toward milder climates in the current evaluation is a key factor in explaining the lower impact estimates relative to the 2005 evaluation. Focusing installations in more extreme climates with higher heating and/or cooling loads will increase savings for these measures and help improve program cost effectiveness.

CHAPTER 1: INTRODUCTION

This report presents impact evaluation results for the California Low-income Energy Efficiency Program (LIEE) for program year 2009. The four investor-owned utilities—Southern California Edison (SCE), Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E), and Southern California Gas (SCG) commissioned the evaluation. The California Public Utilities Commission Energy Division also assisted in the commissioning and management of this evaluation.

The evaluation team was led by ECONorthwest, with extensive analytical and data collection assistance provided by West Hill Energy & Computing, Wirtshafter Associates, Michaels Engineering, Quantum Market Research, and John Stevenson from the University of Wisconsin Survey Research Center.

Table 1 provides a summary overview of 2009 LIEE program participation.[12]

Table 1. PY2009 LIEE Participation by Utility

Utility	LIEE Participants (PY2009)
PG&E	81,516
SCE	71,896
SDG&E	20,835
SCG	66,082

The primary objective of this evaluation is to estimate first-year electric and gas savings for individual measures included in the 2009 LIEE program. Whenever possible, we explored developing estimates for individual measures by important subcategories such as housing type, utility service territory, and climate zone. In those cases where sufficient data were not available, savings values were estimated by measure or for groups of related measures.

1.1 APPROACH

The impact evaluation consisted of three primary components:

- **Preliminary Research.** The preliminary research phase included a comprehensive review of research methods used for similar low-income programs and included the previous impact evaluation studies for the California LIEE Program. This preliminary research review combined with our team's assessment of alternative methods resulted in a detailed research plan, which was submitted to and approved by the utilities and the CPUC Energy Division.

- **Data Collection**. A significant amount of evaluation resources were used to collect primary data through participant phone surveys, non-participant phone surveys, and on-site audits of participating customers. These data were used to enhance the billing regression models and to provide additional context on how energy is used within low-income households targeted by the program.

[12] The 2009 participation numbers were calculated by the evaluation team from datasets supplied by the utilities. Given that the evaluation analysis was done independently, there may be slight differences in measure counts between what is reported here versus other published reports documenting 2009 LIEE program accomplishments.

- **Impact Estimation.** The selected research methods and the results of the data collection were combined to produce estimates of first-year electric and gas for the PY2009 LIEE measures. In those cases where the fixed effects model was not able to produce reliable values, engineering analysis was used to develop impact values for selected measures.

We reviewed the recent impact evaluations in the preliminary research stage and developed our approach to build on the successful elements of these past studies. The ECONorthwest team considered a range of analysis options for evaluating the specific measures covered in the LIEE program. Ultimately, it became clear that a regression-based billing analysis was the only viable alternative given the characteristics of the program, available data, evaluation timeframe, and the budget.

Engineering and monitoring techniques were eliminated as options because they require access to detailed pre-installation data at each home. The time for pre-metering had already passed for PY2009 and developing alternative estimates for all LIEE measures would have been prohibitively expensive. The program as implemented is designed to ensure that all *feasible* measures are installed. Consequently, the program tracking data do not include sufficient detail regarding the pre-installation conditions of the home to apply engineering methods.

Estimating savings using simulations of whole building energy use was also considered and then eliminated as an option as it too was prohibitively expensive and not likely to produce superior results. With the simulation method, the underlying assumptions are typically so general that they do not relate to any specific building, and may not accurately depict the treated population of low-income households. Improving these estimates would have required detailed pre-installation baseline data. For engineering strategies, the baseline would have entailed a detailed description of the pre-installation conditions, such as the results of a blower door test (for infiltration measures), the quantity and condition of the pre-existing insulation, or the number of gallons per minutes used by the existing showerhead. For metering, the pre-installation baseline would be the metered amount of energy used by the equipment prior to the installation. As we have already noted, the opportunity for conducting pre-metering for 2009 LIEE participants has passed.

For these reasons we used a billing regression to estimate impacts for the majority of measures covered in the PY2009 LIEE program. As discussed below, we also used some engineering analysis to estimate impacts for those measures that are new to the 2009 LIEE program.

The specific analysis steps followed in this evaluation are as follows:

1. Used a billing regression model and data from 2008 LIEE participants to estimate impacts for measures that are included in both the 2008 and 2009 LIEE programs.
2. For those measures that were new for the 2009 LIEE program, used engineering analysis and/or modeling to develop savings estimates instead of using a billing regression.
3. For groups of measures where savings could not be attributed to individual measures, attempted a second regression to allocate the share of the group savings to each of the individual measures.
4. Developed versions of the billing model that included a comparison group of non-participants in the sample. The comparison group allowed for the estimation of net impacts (if different from gross) and also incorporated broader market trends (e.g., fuel prices, recession, effect of other efficiency programs).

5. Conducted a phone survey of LIEE participants and eligible non-participants and used their survey results to supplement the billing regression model.
6. Conducted on-site inspections with LIEE participants to obtain additional information on selected measures (evaporative coolers, furnace replacement/repair) and how the installed measures are being used. On-site data were used in a separate regression for these customers in an attempt to further refine the impact estimates for the selected measures.
7. Used the results from the previous steps to calculate overall impacts for the 2009 LIEE Program.

Chapter 3 of this report presents a detailed discussion of our research methods.

1.2 Compliance with California evaluation protocols

The evaluation team designed this study to be consistent with the *California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals*, adopted by the CPUC on June 19, 2006. The estimates of gross demand savings meet the standard for basic rigor and gross energy savings are consistent with the enhanced rigor criteria. Adherence to the protocols is demonstrated by the characteristics of the analysis listed below.

- Energy savings are primarily based on a fixed effects regression model, with twelve months of pre- and post-installation billing data.
- A comparison group of LIEE-eligible customers were selected and the benefits of incorporating the comparison group into the model were assessed.
- Factors that change over time, such as weather, were evaluated and included in the model as indicated.
- Rigorous diagnostics of the regression model were conducted, and adjustments to the model were made accordingly.

Additional components of the evaluation were designed to minimize the possibility of bias and ensure that the process and results are objective and defensible. For example, the information-theoretic approach to model selection was performed to ensure an objective process for choosing the final model.

1.3 Organization of report

The remainder of this report is divided into six chapters.

- **Chapter 2: Program Background** provides an overview of the LIEE Program.
- **Chapter 3: Research Methods** describes the regression model and data collection methods. The engineering analysis used to refine the impact estimates is also discussed in this chapter.
- **Chapter 4: Billing Model Specifications** presents the details of the various billing models used.
- **Chapter 5: Model Estimates to Impacts** describes how the final regression results are used to calculate measure-level impacts.
- **Chapter 6: Telephone and On-Site Survey Results** presents selected findings from the participant and non-participant phone surveys, including a description of participating households and program delivery issues.

- **Chapter 7: Modeling Results** presents the final regression results from the population model used to estimate kWh, kW and therm impacts.
- **Chapter 8: Impacts Results** summarizes the impact calculations by utility and measure.
- **Chapter 9: Conclusions and Recommendations** presents overall conclusions and recommendations drawn from the impact analysis results.

Included with this report as separate documents are the following appendices:

- Appendix A: Survey Instruments (Phone and On-site)
- Appendix B: Phone Survey Responses
- Appendix C: Phone Survey Regression Results
- Appendix D: Detailed Impact Tables
- Appendix E: Memo on Data Screening

CHAPTER 2: PROGRAM BACKGROUND

The LIEE Program provides energy efficiency services to low-income customers of the four investor-owned utilities (IOU's). Historically, these services have been provided at no cost to customers, whose household income meets the guidelines established by the CPUC. To ensure that equipment installations are installed properly, the utilities (or designated agent) provide inspection services.

Low-income energy efficiency programs have been implemented in recognition of the limited financial resources and access that might hinder low-income customer participation in conventional energy conservation programs. The intent was to create equity for customers who might not be able to take advantage of energy efficiency measures or otherwise manage their energy costs, thereby relieving the energy-related difficulties faced by low-income customers.

Across the utilities, the LIEE program includes weather-sensitive and non-weather-sensitive measures as well as energy education. Each utility offers many of the same measures in each of their programs and, as is feasible, installs some mix of these measures. In those areas where gas and electric service are provided by different utilities, the utilities have coordinated efforts so that one contractor provides combined LIEE-services to the home.

In addition to serving low-income customers, the LIEE Program is expected to address numerous key initiatives and directives as outlined in CPUC Decision D.08-11-031 (The Decision).[13] To assist with meeting the objectives outlined in The Decision, the current impact evaluation is designed to aid the IOU's in their efforts to "evolve (the program) into a resource program that garners significant energy savings in our state while providing an improved quality of life for California's low-income population."[14]

In addition to this key directive, The Decision notes that:

- The IOUs shall focus on customers with high energy use, burden and insecurity.
- The IOUs shall adopt a "Whole Neighborhood Approach" to marketing and installation of LIEE measures.
- The IOUs shall enhance outreach to persons with disabilities.
- Customers who have not received LIEE measures since 2002 shall be eligible for new measures.
- Low-income customers shall receive measures with high energy savings, even if they need fewer than 3 measures.[15]

[13] D.08-11-031. This Decision is available at: http://docs.cpuc.ca.gov/WORD_PDF/FINAL_DECISION/93648.PDF.

[14] D.08-11-031, p. 2.

[15] ALJ Kim's modification to the OP47 of the 08-11-031 (released May 2009) notes that the IOUs can install one or two individual measures in a home, as long as the total energy savings achieved by either measure or measures combined yield(s) energy savings of at least either 125 kWh/annually or 25 therms/annually.

2.1 PROGRAM ELIGIBILITY

Eligibility in the LIEE Program is determined by income level and household size. In 2005, the CPUC expanded the LIEE eligibility criteria so the LIEE programs now serve customers at or below 200 percent of the Federal Poverty Level guidelines, regardless of elderly or disability status.[16] The CPUC updates the LIEE income guidelines every year for inflation.

The LIEE program serves both owners and renters. Eligible households must either have an account with a regulated utility or pay an energy bill based on sub-metering to an entity that has a master account with a regulated utility. In areas served by different investor-owned gas and electric utilities (e.g., the SCG/SCE overlap area) the fuel source for the dwelling's space heat determines which utility will be the primary provider of weatherization services to the dwelling. In general, only residential customers on residential rates are eligible to participate in the LIEE Program.

2.2 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 identifies the specific measures offered through the program as provided in the *Statewide Low-income Energy Efficiency Program Policy and Procedures Manual, August 2010* (P&P Manual).

Program guidelines call for the installation of all eligible measures that are feasible. In effect, no household or measure-level cost-effectiveness criteria are applied on a per participant basis. Non-feasibility criteria are provided in the P&P Manual for all measures and 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. When necessary to complete the installation of eligible measures, contractors are also allowed to provide minor home repairs. The P&P Manual provides both household and program budget limits for these activities.

Eligible measures are listed in Table 2, followed by the sixteen climate zones shown in Figure 1.

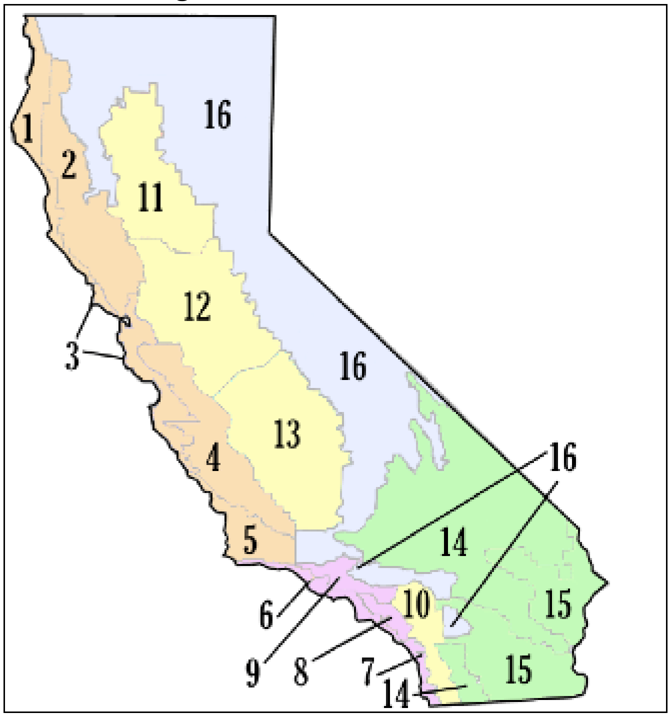
[16] California Public Utilities Commission. Notice to Investor Owned Utilities Providing Service under CARE and LIEE (at 200% of the Federal Poverty Guideline Level). April 28 2009 (http://www.liob.org/docs/2009-2010 Income Eligibility Guidelines - Large Utilities.pdf)

Table 2. LIEE Eligible Measures

Measure	Climate Zone
HVAC	
Heating System Repair & Replace	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16
Gas Furnace Repair/Replace	7,10,15
Forced Air Unit Standing Pilot Light Conversion	All
Furnace Clean & Tune	5,6,7,8,9,10,13,14,15,16
Room A/C Replacement	10, 11, 12, 13, 14, 15, 16
Central A/C Replacement	13, 14, 15
Central A/C Tune-up	2, 4, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16
Central A/C Services	All
Heat Pump	13, 14, 15
Evaporative Coolers	10, 11, 12, 13, 14, 15, 16
Evaporative Coolers Maintenance	All
Infiltration & Space Conditioning	
Envelope and Air Sealing Measures	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16
Envelope and Air Sealing Measures (Except Electric Heated Mobile Homes)	7
Duct Sealing	All
Attic Insulation	All
Water Heating Measures	
Water Heater Conservation Measures	All
Water Heater Replacement - Gas	All
Tankless Water Heater - Gas	All
High Efficiency Clothes Washer	All
Thermostic Shower Valve	All
Lighting Measures	
CFL Lighting	All
Interior Hard-wired CFL fixtures	All
Exterior Hard-wired CFL fixtures	All
Torchiere	All
Occupancy Sensors	All
LED Night Light	All
Other	
Refrigerators	All
Pool Pumps	All
Microwave Ovens	All
Minor Home Repairs	All

Source: Compiled from the Statewide LIEE P&P Manual, Table 5-1.
Notes: There are multiple sub-measures 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.

Figure 1. CEC Climate Zones



2.3 PROGRAM SERVICES

The P&P Manual provides guidelines regarding the information the utilities should provide low-income households during the initial home visit. In particular, the LIEE Program outreach worker is supposed to provide a description of the following services:

- The LIEE Program, including program goals, eligibility requirements, eligible measures, and procedures. This must include energy education, available energy efficiency services and minor home repairs, general installation procedures, inspection procedures, and, if applicable, natural gas appliance testing procedures.
- The existence of other programs, if they are offered as separate programs, designed to repair or replace furnaces or install other energy efficiency measures, if they are offered as a separate program.
- The California Alternate Rates for Energy (CARE) Program. The outreach workers are also to provide assistance in enrolling the customer in CARE if the customer chooses to participate in it.
- Other utility programs designed to provide services to low-income customers, including level-payment programs, medical baseline programs, and other energy efficiency programs for which the customer may be qualified.
- Similar programs offered by the local Department of Community Services and Development (DCSD) agencies and other known energy-related programs.

In addition to the installation of measures, the LIEE Program also includes an energy education component. The energy education component provides guidance on the following:

- General levels of usage associated with specific end uses and appliances;

- 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;
- How to read a utility bill; and
- Procedures used to conduct natural gas appliance testing (if applicable).

CHAPTER 3: RESEARCH METHODS

This chapter describes the data collection methods and sampling strategy used to support the billing regression models. Our overarching goal was to collect data through several channels (phone survey and on-site) to develop additional regression models to complement the population regression model that utilizes all of the participant tracking data. Both the phone survey and on-sites were designed to emphasize several specific measures where it was hypothesized that we may be to develop more robust impact estimates by collecting additional data beyond what was already available in the program tracking data. Details on the data collection and sampling methods are described below.

Previous evaluations using the full data set had failed to produce measurable estimates of the energy saved from heating and cooling measures provided as part of the LIEE package of measures. Because these measures represent a substantial portion of LIEE expenditures, the 2009 LIEE evaluation included several enhancements over earlier LIEE evaluations; focused on building more complete models of the heating and cooling use and savings in treated homes. These enhancements involved both broader data collection and analysis. The data collection efforts added additional questions on heating and cooling use in the telephone and on-site survey and detailed examination of the home characteristics and heating and cooling system components in the on-site survey. The largest amount of additional expenses was devoted to building a far larger set of models using the full data, the phone survey, and the on-sites.

The data collection phase of this study included a phone survey of 1,500 participants and an on-site assessment of 400 participant households. In addition, this year's study also added a phone survey of 1,500 non-participant households. The phone surveys included a battery of questions on household demographics, energy use, influence of the education session, and program satisfaction similar to those used in previous years. This year's surveys also added an extensive battery on the detailed use of heating and cooling equipment before and after LIEE interaction.

The on-site data collection done as part of the 2005 evaluation was focused on measuring savings from water heating and education measures. That collection instrument included measurement of showerhead flow rates and lighting that we did was not included in this year's collection. Instead, the auditors collected measurement of square footage of windows, walls, floor area, and attic areas. The auditor also collected detailed information on all heating and cooling equipment. Finally, the auditor asked detailed questions on equipment use and occupancy changes.

The majority of the extra time spent on this project involved the modeling and analysis task. In previous years, the modeling was done principally using the full participant database. In this year's evaluation we built separate models using the full data set, the full data set with a comparison group, the phone survey sample, and the on-site sample. Extra time was needed to develop each of these models and then additional time was required to true up the results from the different models.

The real achievement of this round of modeling is the inclusion of some of the behavior elements in the phone and on-site analyses. Data regarding prior use of heating equipment is a telling factor in explaining energy savings. Interestingly, data on the physical characteristics of the homes did not prove to be as useful in defining energy savings. Given that the most useful questions were behavioral in nature, it does not appear as though on-site assessments will be required to duplicate the results should this type of study be desired in the future.

3.1 Data Collection

Phone Survey

The primary purpose of the phone surveys was to collect additional information (beyond what was available in the tracking data) that might help develop a more robust billing model. Phone surveys of LIEE participants were conducted in for a sample of LIEE participants from PY2008 (rather than PY2009) to allow for enough post-participation billing data to support a billing regression model. A similar phone survey was fielded for a sample of non-participants. The participant survey was fielded from April through July of 2010 and the non-participant survey was fielded from May through July of 2010. Additional detail on the various sampling strata and number of completes is provided later in the discussion of sampling.

A target sample size of 400 participants was selected for each measure group of interest:

- Furnace Replace
- Furnace Repair
- Evaporative Cooler
- Weatherization measures

The data from the telephone survey were used to develop four separate billing regression models—one each for the four weather sensitive measures. The information gathered through the telephone surveys, were used as explanatory variables in the billing regressions. The purpose of the estimating measure-specific billing models is to determine if such models provide a better way to develop estimates of *change-in-energy-use* associated with each of the four measures of interest than does a billing model that includes all participants, but does not include information gathered through a participant survey.

Information collected through the participant phone survey included:

- Demographic data
- Housing characteristics (home size, vintage, appliances)
- Changes to household during the analysis period (occupancy, large appliance purchases, remodels)
- Any other changes to the household or dwelling that may significantly affect energy usage
- Self-report battery of free ridership questions to estimate the likelihood that the measures would have been installed in absence of the LIEE program.
- Attitudes and knowledge about energy efficiency
- Use of the equipment installed through the LIEE program.

A similar non-participant survey was fielded to collect information from a control group of low-income households. The information on non-participants was combined with data from the participants in a variation of the phone survey billing regression model. To help ensure that the non-participant sample was an appropriate control group, a sample of LIEE participants was used from PY2009 as a control group for PY2008 under the assumption that the household characteristics would be similar across participant and non-participant groups. The non-participant survey was fielded from May through July of 2010. Information collected from the non-participant survey was designed to match as much as possible with the participant survey and include:

Information collected through the non-participant phone survey included:

- Demographic data
- Housing characteristics (home size, vintage, appliances)
- Changes to household during the analysis period (occupancy, large appliance purchases, remodels)
- Any other changes to the household or dwelling that may significantly affect energy usage

The survey instruments and tallies of responses for both the participant and non-participant surveys are included in *Appendix A.*

On-site Survey

An additional data collection element was a post-installation, on-site survey to conduct a technical review of the program implementation from a sample of participants. Our approach was patterned after the one used in the PY2005 but included a more extensive data collection effort while on-site.

The on-sites were designed to research possibilities for improving program cost-effectiveness and to provide supporting research for the qualitative analysis of the energy education component. The survey assessed the quality of installation, measure retention, reasons for removal of measures, missed opportunities, post-installation use of the efficient equipment, and behavioral changes made as a result of the program. The on-site survey also provided the opportunity to investigate the installation, use, and behavioral issues that may affect savings from the equipment installed through the program.

The survey consisted of two parts: 1) a semi-structured interview to assess the participant's response to the energy education and understanding of the use of the installed equipment and 2) a detailed walk-through of the home to identify the presence of the installed measures and lost opportunities. The evaluator identified eligible measures that were not installed and ineligible measures that were installed. The evaluator also assessed other opportunities for savings.

We conducted 400 on-site surveys of single-family homes. We used cluster sampling to keep travel costs within a reasonable range and the clusters were sufficiently large to avoid the consistent grouping of similar housing stock. The samples were divided into heating and cooling sub-samples. One consisted of homes that received evaporative coolers or air conditioners, the second of homes that received furnace repairs or replacements. These issues were incorporated into the sample design process discussed below.

To research the impacts of energy education, participants were initially asked to volunteer what they remember from the audit. They were also asked (without prompting) what they are currently doing to save energy. A follow-up set of questions allowed for aided recollections. Participants were also asked about how they use the efficient products installed through the program and any problems or issues that have developed with these products.

A second battery of questions delved into the use of the heating and cooling equipment before and after treatment. These questions provide a more comprehensive picture of space conditioning equipment use patterns. Their availability allows us to build models that account for previous use and changes in use over the study period.

The technical part of the on-site survey was to verify the presence of the installed products, identify any eligible measures that were not installed as well as installed measures that were not eligible (where possible to ascertain), and any other energy savings opportunities that may not currently be on the list of eligible measures.

3.2 Sampling Strategy

Phone Survey

The phone survey sample was designed to achieve a relative precision level of 90/10 for each of the four major measure groups of interest. The sampling plan followed the general steps laid out in the *California Evaluation Framework (Framework)*, with specific sample design determined from the actual participation data. The general sampling steps were as follows:

Step 1: Data Collection. Obtain participant (2008 LIEE Participants) and non-participant (2009 LIEE Participants) data from each utility. The participant and non-participant data were used to develop two separate sampling frames.

Step 2: Examine the distribution of households by expected energy savings. Basic descriptive statistics were computed for the participant and non-participant data, including mean, standard deviation, coefficient of variation (CV), population size.

Step 3: Calculate the required sample size. The determination of sample size was based on standard sampling equations contained in the *Framework* based on 90/10 level of confidence/precision required for this evaluation. We developed our survey quotas based on a general guideline of needing roughly a ten-to-one ratio of sample data to survey quota for the major measures covered in this evaluation.

Step 4: Determine if qualitative stratification should be used. The focus of the telephone surveys and the billing regression modeling based on the telephone survey was four temperature sensitive measures: evaporative coolers, furnaces, furnace repair, and weatherization. Because of this, for both the participant and non-participant sampling frames, the data were stratified by measure installed and by one of three temperature zones: “more extreme heat” defined as areas with annual heating degree days (HDD) greater than 2,100 HDD; “more extreme cold” defined as areas with annual cooling degree days (CDD) greater than 2,100 CDD; “mild temperature” defined as areas with annual HDD and CDD less than 2,100.

In order to accommodate the four measures of interest and the three defined temperature zones, we developed 11 strata for each of the participant and non-participant data sets:

1. Furnace Replace (Non-Extreme Temp)
2. Furnace Replace (Extreme-HDD)
3. Furnace Replace + Weatherization (Extreme-HDD)
4. Furnace Replace + Weatherization (Non-Extreme Temp)
5. Weatherization Only (Non-Extreme Temp)
6. Weatherization Only (Extreme-HDD)
7. Weatherization Only (Extreme-CDD)

8. Evaporative Cooler (Non-Extreme Temp)
9. Evaporative Cooler (Extreme-CDD)
10. Furnace Repair (Non-Extreme Temp)
11. Furnace Repair (Extreme-HDD)

Step 5: Draw the sample. The total sample size was allocated among the strata with greater than proportional representation for those strata based on temperature zones of more extreme heat and more extreme cold. The allocation of sample points by stratum is shown in Table 4 and Table 5 below. It is in homes located within areas of more extreme temperature (either greater heat or greater cold) that installation of the four weather sensitive measures of interest should show an impact. Because there are relatively few participant homes located within these more extreme temperature zones, we oversampled these strata in order to develop more precise estimates of energy impacts associated with areas of more extreme temperature.

Phone Survey Sample Stratification

The measure groups for the phone survey quotas are defined as follows:

- Furnace Replace: Customer received a furnace replacement through the program
- Furnace Repair: Customer had furnace repairs completed through the program
- Evaporative Cooler: Customer had an evaporative cooler installed through the program.
- Weatherization: Customer had a weatherization measure installed through the program, including insulation, caulking, and weatherstripping.

In order to reduce any confounding effects associated with installation of multiple temperature sensitive measures, to the extent possible, we focused the sampling points on those homes that had only one of the four categories of temperature sensitive measures installed.

The ECONorthwest Team looked at a variety of strategies for defining climate strata. Initially, we considered the climate region categories included in the LIEE Policies and Procedures Manual.[17] The mapping of the five zones to the 16 CEC climate zones is as follows:

- Region 1 (North Coast): CEC Zones 1,2,3,4,5
- Region 2 (South Coast): CEC Zones 6,7,8,9
- Region 3 (Inland): CEC Zones 10,11,12,13
- Region 4: (Desert): CEC Zones 14, 15
- Region 5: (Mountain): CEC Zone 16

The problem with this approach is that heating and cooling degree days are highly variable within these regions. Table 3 demonstrates this variation and is based on weather data collected for the 2005 LIEE impact evaluation.

[17] See map on page 7-8 of the *Low-Income Energy Efficiency Program Statewide Policy and Procedures Manual* (December 2003).

Table 3. Summary of Weather Data by Region

Region	Minimum Annual HDD	Maximum Annual HDD	Average[a] Annual HDD	Minimum Annual CDD	Maximum Annual CDD	Average[a] Annual CDD
1	1,551	4,176	2,705	0	1,013	129
2	969	2,358	1,604	5	355	99
3	972	5,598	2,284	5	2,014	374
4	872	2,964	1,839	153	2,083	1,124
5	972	7,849	2,838	0	2,014	451

[a] The annual heating degree days (HDD, base 65) and cooling degree days (CDD, base 75) were averaged over all of the weather stations in the region.

The distribution by the 16 CEC climate zones was also considered with a similar result. Consequently, the ECONorthwest team proposed to establish two climate categories for heating and two for cooling ("mild" and "more extreme") based upon the actual weather data as calculated for each participant. The actual cut offs come to plus or minus 2100 heating degree days and plus or minus 2100 cooling degree days. This allocates 75% of the sample size to the milder climates and 25% to the more extreme climates. This approach provides an oversample of the extreme climates, allowing for additional information about the potential for savings in the regions with more extreme weather conditions.

Housing type was not selected as a stratification variable. Sample sizes of 400 per measure group, including multiple housing types would increase the variation in the sample and could affect the validity of the results. In addition, review of the 2008 program data indicates that the vast majority of the furnace and evaporative cooler installations occurred in single family homes (89% and 75% respectively). While mobile homes account for 16% of the evaporative cooler installations, experience from previous evaluations suggests that mobile home parks are often master-metered and billing data will not be available for a high percentage of these homes.

Weatherization measures are more evenly divided, with 63% installed in single family homes, 31% in multifamily homes and the remaining 6% in mobile homes. However, the savings from weatherization measures are likely to be quite small, and it is likely to be difficult to obtain reliable results from the regression models. Adding variability to the sample will only exacerbate this issue. We will review other methods for ensuring that the results from the single family sample are correctly applied to mobile homes and multifamily buildings, such as adjusting weather-specific savings based on the average heat load for the housing type.

The primary purpose of this exercise is to improve the estimates of savings for these distinct measure groups. However, there is a high degree of overlap between weatherization, furnace and evaporative cooler installations and interactive effects tend to reduce the savings from combined installations as compared to the installation of the individual measures, particularly for furnaces. For the evaporative coolers, there are likely to be less interactive effects with weatherization since it is recommended practice to leave a window open when the evaporative cooler is in operation.

The second consideration is that the regression model is more likely to be effective with fewer confounding factors. Since the savings from both weatherization and furnaces are weather-dependent and will be concurrent, it will be more difficult to separate the savings from the two measures in homes with both. Focusing primarily on homes with only furnaces or only weatherization will improve the likelihood of obtaining reliable results from the phone survey regression models.

Given these issues, the ECONorthwest team proposed to select participants that received only one of the following four measures: furnace, furnace repair, evaporative cooler, or weatherization and to focus the majority of the sample points on homes located within the “more extreme” climate areas. However, as Table 4 shows, there were very few households within a designated “extreme” cold climate area that received a furnace (strata 2 and 3) and there were only 13 participants that received a new furnace, but did not receive weatherization measures. Thus, the vast majority of sample points devoted to furnaces were for homes located in areas that experience only mild cold temperatures. There were also relatively few participants that received furnace repair for homes located within a “more extreme cold” area (strata 11 in Table 4). Therefore, most of the sample points for furnace repair were concentrated in areas of mild temperature.

The number of homes that received weatherization, but not a furnace, furnace repair, or an evaporative cooler (the “weatherization only” group) is quite large and we were able to fill a roughly equal number of sample points for homes located in areas of “more extreme cold,” “more extreme heat,” and mild temperatures (strata 5, 6, and 7). Likewise, there was a large number of participants that received evaporative coolers, but did not receive weatherization (or furnace/furnace repair). Because of this we were able to fill out our sample quota for homes located in areas of “more extreme heat” and mild temperature (strata 8 and 9).

Table 4 and Table 5 show the final stratification and actual number of completes for the participant and non-participant surveys.

Table 4. Sample Stratification and Number of Completes, Participant Survey

Strata	Measure	Weather Type	Population	Survey Quota	Completed Surveys
1	New Furnace Only	Mild	935	200	196
2	New Furnace Only	Extreme	13	Exhaust	4
3	New Furnace & Weatherization	Extreme	44	Exhaust	24
4	New Furnace & Weatherization	Mild	2,393	400 minus Σ(Strata 2-4 Completes)	223
5	Weatherization Only	Mild	51,905	200	149
6	Weatherization Only	Extreme Cold	3,672	100	134
7	Weatherization Only	Extreme Heat	2,287	100	122
8	Evaporative Cooler Only	Mild	3,402	300	275
9	Evaporative Cooler Only	Extreme	2,111	100	101
10	Furnace Repair Only	Mild	883	300 minus Σ(Strata 11 Completes)	250
11	Furnace Repair Only	Extreme Cold	54	Exhaust	21
	Total		**67,699**	**1,500**	**1,499**

Table 5. Sample Stratification and Number of Completes, Non-Participant Survey

Strata	Measure	Weather Type	Population	Survey Quota	Completed Surveys
NP-1	New Furnace	Mild	185	Exhaust	43
NP-2	New Furnace	Extreme	11	Exhaust	6
NP-3	New Furnace	Extreme	28	Exhaust	15
NP-4	New Furnace	Mild	997	400 minus Σ(Strata 2-4 Completes)	249
NP-5	Weatherization	Mild	2,491	200	200
NP-6	Weatherization	Extreme Cold	2,484	100	102
NP-7	Weatherization	Extreme Heat	2,488	100	100
NP-8	Evaporative Cooler	Mild	1,923	300	301
NP-9	Evaporative Cooler	Extreme	342	100	100
NP-10	Furnace Repair	Mild	363	Exhaust	135
NP-11	Furnace Repair	Extreme Cold	61	Exhaust	34
NP-12	New Furnace or Evaporative Cooler and Weatherization		2,487	1,500 minus Σ(Strata 1-11 Completes)	218
	Total		**13,860**	**1,500**	**1,503**

On-Site Survey

The sampling strategy for the on-site sample is described below. The original sample was to contain 200 homes that received an evaporative cooler and 200 homes that received furnace replacement or repair. Recruitment of homes was divided so that we were sure that there would be homes in both sectors that were from areas with higher degree days. As in the phone survey those divisions were +/- 2100 degree days for both heating and cooling. A total of 416 homes were visited however, 16 on-site surveys could not be conducted because the occupants were not at their home at the scheduled time, and 22 of those homes were mislabeled as having had furnace repair or evaporative cooler jobs. Those mislabeled households were not included in the models.[18]

Table 6 compares the distribution of homes in the treated population and the actual samples for heating and cooling. The on-site sample for heating measures is similar to the population of homes receiving heating measures. Due to the sampling strategy, the on-site sample has a higher proportion of homes in the more severe cooling climate than were found in the general population.

[18] The mislabeling occurred during the initial grouping of common measures across utilities by the evaluation team; evaporative cooler covers were grouped with evaporative cooler installations, and furnace filters were grouped with furnace repair measures. While this resulted in the loss of a few useful data points in the on-site regressions, it is unlikely that the omission of these points had any significant effect on the modeling results.

Table 6. Comparison of Population and Sample Distributions

	Population of Homes Receiving Heating Equipment or Repair (PY2008-09)		On-site Sample of Homes Receiving Heating Equipment or Repair	
	Number of Sites	**Percent**	**Number of Sites**	**Percent**
HDD<2100	11,116	77%	142	75%
HDD>2100	3,290	23%	47	25%
Total all Heating	14,406		189	
	Population of Homes Receiving Evaporative Coolers (PY2008-2009)		**On-site Sample of Homes Receiving Evaporative Coolers**	
	Number of Sites	**Percent**	**Number of Sites**	**Percent**
CDD<2100	7,904	78%	142	81%
CDD>2100	2,228	22%	34	19%
Total all Cooling	10,132		176	

CHAPTER 4: BILLING REGRESSION SPECIFICATIONS

The regression models focuses on three separate models that relied on different data sources:

- **Population model.** The population model utilized the entire participant dataset from PY2008, less those observations that were removed due to the data cleaning process. A similar population dataset from the PY2009 LIEE participants was used as a control group in a variation of this model.
- **Phone survey model.** This model used data from 2008 LIEE participants that were surveyed by phone. While this dataset is much smaller than the population model, it has the potential advantage of containing additional information obtained through the phone survey that is not routinely tracked in the participant tracking dataset. Due to the smaller sample, the phone survey focused on selected measures where it was hoped the phone survey regression model might provide robust impact estimates.
- **On-site model.** The on-site regression model that used data from 400 on-site visits conducted during this evaluation. These on-site visits confirmed the LIEE measures were installed and collected additional information on energy use and home characteristics that were not available through the phone survey or included as part of the participant tracking data.

The model specifications for each of these regressions are described below, with estimation results included in the following chapter.

4.1 POPULATION MODEL

This section describes the population regression models that are estimated from data from the entire LIEE participant tracking system. Ideally, we would estimate the billing regression model using pre- and post-participation billing data from 2009 program year participants. The disadvantage of trying to use only 2009 participant data was timing. For a billing analysis, at least 12 months of post-installation data are needed. If only 2009 participants were used, we would not have had enough billing data until October 2010, at the earliest. This would not have given us enough time to conduct the impact analysis and produce a report in the time allocated for this evaluation.

To address the timing issue, we estimated the billing regression model using data for PY2008 participants and non-participants for those measures that are the same for both PY2008 and PY2009. For those measures installed by the LIEE program in both 2008 and 2009, the measure-level savings are likely to be the same for both years, as the measures are identical, the target population is the same, and program delivery for these measures is the same. As a consequence, we took the results from the 2008 billing regression and applied them with confidence to the 2009 program participants for those measures that are included in both program years. This approach is consistent with many other impact evaluations (such as the other impact evaluations recently completed by the CPUC) where multiple years are typically covered by one evaluation and data from a portion of the multi-year period are used to estimate impacts for the entire period.

For the population model, we also estimated a series of models that include a comparison group of non-participants along with the participant data. After exploring options to select an appropriate comparison group, we decided to use 2009 program year LIEE participants as the comparison group. The customers are by definition non-participants in 2008, the period used for the billing regression. They also have some information included in the 2009 program year tracking data, which help facilitate the sample development and phone surveys.

The need for a complete data set requires us to trim the original population to those who have sufficient pre- and post- billing data. In some studies, this can lead to a large drop in the number of usable cases. While there will always be some customers that either are screened out explicitly the issue is whether savings for these customers are likely to be significantly different than savings for those customers that remain in the sample.

Because of issues of collinearity between factors and the interactive effects of other factors, it is often advisable to review the measure overlap patterns to determine which measures should be jointly modeled and which can be effectively separated. In our models, we use both combined and separate measures. A complete picture of these types of measures are described in the model descriptions, below.

After we developed the billing analysis datasets for participants and the non-participant comparison group, we estimated two different versions of the billing regression models:

1. **Participant Only Model**. This is basically the model estimated in the PY2005 impact evaluation using only participant data. With this model, the model results are interpreted as gross impacts.

2. **Participant and Non-participant Model.** Since the non-participant group is included, any efficiency actions occurring outside the program were incorporated in the model. Consequently, the model results can be interpreted as net impacts.

Fixed Effects Model

Estimates of measure savings were obtained from fixed-effects models of monthly electricity and natural gas usage, similar to the models used in other recent impact evaluations (including the PY2002 and PY2005 LIEE impact evaluations). Since the population model had sufficient billing data available across all home and measure types, we structured the model to allow estimates of program savings by measure class and home type. The end result of the billing model was used to develop gross impacts estimates at the measure level, where possible.

The general form of the fixed effects model is as follows:

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

Where :

$C =$ *Monthly consumption for the household i in period t, expressed in monthly kWh (or therms) per day*

$\alpha =$ *"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; these effects are assumed to be fixed over the analysis period.*

$\tau =$ *"Time - specific" error for period t, reflecting the unexplained difference in use between time periods, such as greater electricity use during the darker winter months or a widespread change in consumption from an external stimulus.*

$x =$ *Predictor variables reflecting the installation of energy efficiency measure j for household i in period t; in a dummy variable model, the x's are 0 during the pre - installation period and 1 during the post - installation period.*

$\beta =$ *Slope coefficients that quantify the average influence of modeled efficiency measure j on monthly consumption.*

$p =$ *Total number of energy efficiency measures included in the model.*

$z =$ *Predictor variables reflecting non - program related effect k for household i in period t; these variables model factors that change over time during the analysis period, such as weather impacts or change in occupancy.*

$\gamma =$ *Slope coefficients that quantify the average influence of modeled non - program related effect k on monthly consumption.*

$k =$ *Total number of non - program related effects included in the model.*

$\varepsilon =$ *Error term that accounts for the diffeence between the model estiamte 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 $\tau_,$ which represents the variation in use over all homes from one period to the next.

Table 7 and Table 8 provide definitions for the variables used in both the gas and electric population models.

Table 7. Population Regression Model Variable Descriptions-Gas

Variable Name	Description	Units
Thm	Monthly gas consumption, normalized to standard month	therm per month
BillingYear	Time trend variable beginning in 2007 (1=2007, 2= 2008, … , 4= 2010) corresponding to the year of the gas meter read date	1-4
Pre_NoHeat*HDD	Heating slope during pre-installation period for homes with no heating measures, interacted with heating degree days	(0,1) * Days
NoHeat*HDD	Heating slope for homes with no heating measures, interacted with heating degree days	(0,1) * Days
Measure Variables The following variables are dummy variables indicating if the participant had the program measure installed in the given month. If a participant received the measure, it would hold the value "0" in all months prior to its installation by the program and "1" in all months following its installation. If a participant did not receive the measure, it would hold the value "0" in all months. **Use Levels** Many of the measure variables, below, are stratified by either the energy use level or the ratio of energy use to degree days of the participant in the time period before program measure installation. For terms that are interacted with heating degree days, the use level is defined using the ratio of energy use to heating degree days. For terms that are not interacted with heating degree days, the use level is defined using only energy use. The four use level categories were designated as follows: "1" denotes those participants in the 10th percentile and below; "2" those between the 50th and 10th percentiles; "3" those between the 90th and 50th percentiles; and "4" those above the 90th percentile. **Weather-sensitive measures** Many of the measure variables, below, are weather-sensitive. The main effect for these variables was restricted to the appropriate season. The effect of this is that the measure variable holds the value of "1" only in the months following its installation that are also in this appropriate season, and "0" in all other months.		
DHW1-4	Measure variable for the domestic hot water conservation package measures, by pre-installation use level.	(0,1)
WaterHeater	Measure variable for water heater repair or replacement.	(0,1)
Weather1-4*HDD	Interaction effect measure variable for enclosure ("weatherization") measures, by pre-installation use level, interacted with heating degree days, for those participants who did not receive any other heating measures.	(0,1) * Days
WeatherSlope1-4*HDD	Heating slope for homes with weatherization measures, by pre-installation use level, interacted with heating degree days, for those participants who did not receive any other heating measures.	(0,1) * Days
HeatingSystem1-4*HDD	Interaction effect measure variable for furnace repair or replacement, by pre-installation use level, interacted with heating degree days, for those participants who received a furnace measure and did not receive insulation.	(0,1) * Days
HeatingSystemSlope1-4*HDD	Heating slope for homes with furnace repair or replacement, by pre-installation use level, interacted with heating degree days, for those participants who received a furnace measure and did not receive insulation.	(0,1) * Days
Insulation1-4*HDD	Interaction effect measure variable for insulation measures, by pre-installation use level, interacted with heating degree days.	(0,1) * Days
InsulationSlope1-4*HDD	Heating slope for homes with insulation, by pre-installation use levels, interacted with heating degree days.	(0,1) * Days
Ducts1-4*HDD	Interaction effect measure variable for ducts measures, by pre-installation use level, interacted with heating degree days, for those	(0,1) * Days

DuctsSlope1-4*HDD	participants who did not receive insulation or a heating system measure. Heating slope for homes that received ducts and did not receive insulation or a heating system measure, by pre-installation use level, interacted with heating degree days.	(0,1) * Days

Table 8. Population Regression Model Variable Descriptions-Electric

Variable Name	Description	Units
kWh	Monthly electricity consumption, normalized to standard month	kWh per month
BillingMonth	Time trend variable beginning in January 2007 (1=January 2007, 2=February 2007, … , 13=January 2008, … , 44=August 2010) corresponding to the month of the electric meter read date	1-44
NonWorkingAC_AC*CDD	Cooling slope for those homes with a non-working Air Conditioner who received an air conditioner, interacted with cooling degree days	(0,1) * Days
NonWorkingAC_Evap*CDD	Cooling slope for those homes with a non-working Air Conditioner who received an evaporative cooler, interacted with cooling degree days	(0,1) * Days
NoHeatSlope1-4*HDD	Heating slope for those homes that did not receive any heating measures, by pre-installation use level, interacted with heating degree days.	(0,1) * Days
NoCoolSlope1-4*CDD	Cooling slope for those homes that did not receive any cooling measures, by pre-installation use level, interacted with cooling degree days.	(0,1) * Days
Measure Variables The following variables are dummy variables indicating if the participant had the program measure installed in the given month. If a participant received the measure, it would hold the value "0" in all months prior to its installation by the program and "1" in all months following its installation. If a participant did not receive the measure, it would hold the value "0" in all months. **Use Levels** Many of the measure variables, below, are stratified by either the energy use level or the ratio of energy use to degree days of the participant in the time period before program measure installation. For terms that are interacted with heating degree days, the use level is defined using the ratio of energy use to heating degree days, and for terms that are interacted with cooling degree days, the use level is defined using the ratio of energy use to cooling degree days. For terms that are not interacted with heating degree days, the use level is defined using only energy use. The four use level categories were designated as follows: "1" denotes those participants in the 10th percentile and below; "2" those between the 50th and 10th percentiles; "3" those between the 90th and 50th percentiles; and "4" those above the 90th percentile. **Weather-sensitive measures** Many of the measure variables, below, are weather-sensitive. The main effect for these variables was restricted to the appropriate season. The effect of this is that the measure variable holds the value of "1" only in the months following its installation that are also in this appropriate season, and "0" in all other months.		
CFL	Measure variable for CFLs.	(0,1)
HardwiredFixtures	Measure variable for Hardwired Fixtures.	(0,1)
Refrig1-4	Measure variable for refrigerators, by pre-installation use level.	(0,1)
PoolPump	Measure variable for pool pumps.	(0,1)
DHW1-4	Measure variable for the domestic hot water conservation package	(0,1)

	measures, by pre-installation use level.	
Weather*CDD	Interaction effect measure variable for air sealing / envelope ("weatherization") measures, interacted with cooling degree days.	(0,1) * Days
WeatherSlope*CDD	Cooling slope for homes that received weatherization and no other cooling measure, interacted with cooling degree days.	(0,1) * Days
Weather*HDD	Interaction effect measure variable for air sealing / envelope ("weatherization") measures for those homes that have electric space heating, interacted with heating degree days.	(0,1) * Days
WeatherSlope*HDD	Heating slope for homes that received weatherization and have electric space heating, interacted with heating degree days.	(0,1) * Days
Evap1-3*CDD	Interaction effect measure variable for evaporative cooler measures, by pre-installation use level, interacted with cooling degree days, for those participants who received an evaporative cooler and did not receive an air conditioner.	(0,1) * Days
EvapSlope1-3*CDD	Cooling slope for homes that received an evaporative cooler and did not receive an air conditioner, and "0" otherwise, by pre-installation use level, interacted with cooling degree days.	(0,1) * Days
AC1-3*CDD	Interaction effect measure variable for air conditioning measures, by pre-installation use level, interacted with cooling degree days, for those participants who received an air conditioner.	(0,1) * Days
ACSlope1-3*CDD	Cooling slope for homes that received an air conditioner, by pre-installation use level, interacted with cooling degree days.	(0,1) * Days
Insulation1-3*CDD	Interaction effect measure variable for insulation measures, by pre-installation use level, interacted with cooling degree days, for those participants who did not receive an air conditioner or evaporative cooler measure.	(0,1) * Days
InsulationSlope1-3*CDD	Cooling slope for homes that received insulation and did not receive an air condition or evaporative cooler measure, by pre-installation use level, interacted with cooling degree days.	(0,1) * Days
Insulation1-4*HDD	Interaction effect measure variable for insulation measures, by pre-installation use level, interacted with heating degree days, for those participants who have electric space heating.	(0,1) * Days
InsulationSlope1-4*HDD	Heating slope for homes that received insulation and have electric space heating, by pre-installation use level, interacted with cooling degree days.	(0,1) * Days

Model Specification Process

Given the numerous possible combinations of the variables shown in the previous tables, a systematic method was used to explore definition model specifications, starting with a simple specification and gradually becoming more complex. This process is described below for the electric model, an analogous process was used for the gas model.

As discussed above, all the population models as fixed effects models with customer-specific intercepts and time trend variables by month to control for widespread changes over time. All heating and cooling-related measures have two variables: one that reflects the overall heating or cooling use over the entire period and a second one that reflects that change in use during the post-installation period.

The model specification process followed these steps:

1. **Simple model.** No measure variables, post-installation period and post-installation interacted with cooling degree days, main effects heating and cooling degree days.
2. **Model with measures.** Based measures added to the simple model, along with evaporative cooler and AC measure. Includes interaction with cooling degree days for homes with working AC and no cooling measure and interaction with heating degree days for homes with electric space heat.
3. **Heating and cooling measures.** All heating and cooling-related measures were defined by hierarchy; each home was assigned to one measure. For heating measures the order was as follows: insulation, duct sealing, weatherization. For cooling measures, the order was evap cooler, efficient A/C, insulation, duct sealing, weatherization.
4. **Insulation/weatherization measures.** Insulation and weatherization measures added for heating (electric space heat) and cooling (working AC)
5. **Use levels for base measures.** Different use categories are added for refrigerators and DHW conservation. Note that lighting and pool pumps were not estimated by use level and there are not enough homes with pool pumps in the regression data set to estimate by use level. Conversely, lighting measures are installed in almost all homes and estimating the savings by use level is likely to pick up general differences across the use levels rather than the lighting savings.

Use levels were defined based on pre-installation annualized use and is consistent with the method used in the PY2005 LIEE evaluation. The four use category definitions for the base measures are shown in Table 9.

Table 9. kWh Use Categories for Base Measures

Use Level	Description	Minimum Annualized kWh Use	Maximum Annualized kWh Use	% of Participants
1	Very low use		2725	10%
2	Low use	2725	5054	40%
3	Moderate use	5054	8621	40%
4	High use	8621	(no limit)	10%

A similar strategy was followed to add use levels to the estimates for evaporative coolers, ACs, attic insulation (cooling). Use levels were defined based on pre-installation cooling use; the cooling use was calculated by summing the kWh use and cooling degree savings over the cooling months (May through September) and determining the kWh/CDD ratio. This method is a further refinement of the approach used in the 2005 LIEE Impact Evaluation in that the usage bins for the cooling measures are based on the cooling use during the pre-installation period. The four use categories for this step are shown in Table 10.

Table 10. kWh Use Categories for Cooling Measures

Use Level	Description	Minimum Summer kWh/ Summer Cooling DD	Maximum Summer kWh/ Summer Cooling DD	% of Participants
1	Very low use		1.118	10%
2	Low use	1.118	2.383	40%
3	Moderate use	2.383	9.400	40%
4	High use	9.400	(no limit)	10%

For the heating component of attic insulation, heating use levels were calculated in the same manner, using the kWh during the winter months (November through March) and the heating degree days during the same period (shown in Table 11)

Table 11. kWh Use Categories for Heating Measures

Use Level	Description	Minimum Winter kWh/ Winter Heating DD	Maximum Winter kWh/ Winter Heating DD	% of Participants
1	Very low use		0.6424	10%
2	Low use	0.6424	1.2607	40%
3	Moderate use	1.2607	2.3722	40%
4	High use	2.3722	(no limit)	10%

Finally, use levels were added for homes with electric space heat and no heating measures and with working A/C and no cooling measures using the same use level definitions as defined above. Additional variables were also added to capture potential extra use for homes with no working A/C in the pre-installation period and receiving an evaporative cooler or efficient A/C through the program. This was done by running two different models; one with two dummy variables (A/C and evaporative cooler) and one with the two variables dividing into cooling use level (the latter one was the model ultimately chosen as the final model for this evaluation).

In addition, other model specifications were attempted using all of the heating and cooling measures with use levels defined by the base use level rather than the heating or cooling use level. (This was also the strategy used in the PY2005 LIEE Impact Evaluation.)

A similar process was followed to develop the gas models:

- All models are fixed effects, have customer-specific intercepts, and are time variable (in order to account for widespread changes over time).
- All heating-related measures have two variables: one that reflects the overall heating use over the entire period and another that reflects the change in use during the post-installation period.
- All heating-related measures were defined by hierarchy—each home was assigned to one measure. The order was: 1) insulation, 2) heating system repair/replacement, 3) duct sealing, and 4) weatherization.

The model selection process followed these steps:

1. **Simple model.** No measure variables, post-installation period and post-installation interacted with heating degree days nor main effects heating degree days.
2. **Model with measures.** Based measures by season added to the simple model, along with combined heating-related measures that interacted with heating degree days. Also includes interaction with heating degree days for homes with gas space heaters and no heating-related measures.
3. **DHW measures.** Conservation and replace/repair measures were added, in addition to three heating-related measures (insulation, weatherization, and all other measures combined.

4. **Additional heating-related measures.** Separate ducts from heating system repair/replacement added.
5. **Use levels for DHW conservation measures.** There were not enough homes with DHW replace/repair in the regression dataset to estimate by use level.

Use levels were defined based on pre-installation annualized use, consistent with the method used in the PY2005 LIEE evaluation. The four use category definitions for the base measures are shown in Table 12.

Table 12. Therm Use Categories for Base Measures

Use Level	Description	Minimum Annualized Therm Use	Maximum Annualized Therm Use	% of Participants
1	Very low use		119	10%
2	Low use	119	314	40%
3	Moderate use	314	512	40%
4	High use	512	(no limit)	10%

For the heating component of insulation, heating use levels were calculated by summing the therm use and heating degree savings over the heating months (November through March) and determining the therm/HDD ratio (shown in Table 13). This method is a further refinement of the approach used in the 2005 LIEE Impact Evaluation in that the usage bins for the heating measures are based on the heating use during the pre-installation period.

Table 13. Therm Use Categories for Heating Measures

Use Level	Description	Minimum Winter therms/ Winter Heating DD	Maximum Winter therms/ Winter Heating DD	% of Participants
1	Very low use		0.0472	10%
2	Low use	0.0472	0.1292	40%
3	Moderate use	0.1292	0.2356	40%
4	High use	0.2356	(no limit)	10%

Finally, use levels were added for homes with weatherization measures and for homes with heating system repair/replace using the same use-level definitions as defined above. In addition, other model specifications were attempted using all of the heating measures with use levels defined by the base-use level rather than the HDD-based use level. We also estimated a model that incorporated snap-back or takeback by including all homes with heating-related measures interacting with heating degree days.

Once all the various electric and gas models were run, the optimal was identified using the AIC method described at the end of this chapter.

4.2 Phone Survey Billing Regression Model

The phone survey billing regression model follows a similar structure as the population regression model, but relies on a much smaller sample of LIEE participants that completed the phone survey conducted as part of this evaluation. Unlike the population model, which accounts for difference between households through the fixed-effects panel data specification, the intention of the phone survey billing model was to account for time-invariant household characteristics that are hypothesized to affect energy use, as well as account for household characteristics that may have changed during the study period.[19]

A primary objective of the phone survey billing regression was to develop estimates for four high interest measures: evaporative coolers, furnaces, furnace repair, and weatherization. Because of the smaller sample size associated with the phone survey model (relative to the population model), our *a priori* assumption was that we would not be able to develop estimates of energy savings for the many other measures other than the four targeted measures. This assumption was confirmed early in the modeling process. Consequently, our modeling approach focused on developing individual regression models for each of the four measures.

For the analysis, we developed random-effects panel data models to estimate changes in household electricity usage and natural gas consumption between the baseline and post-measure-installation periods. The billing regression models relate energy consumption to household specific characteristics, outside temperatures, indicator variables for month-of-year. An indicator variable for the months in which the measure of interest was installed was also included, as well as the interaction between the measure indicator and the temperature variables. Like the population regression model, the phone survey model was estimated using the actual levels of energy consumption and the levels of the explanatory variables.

A standard approach for conducting billing analysis is to organize the data by time period (i.e., month) for each participant, which creates a cross-sectional, time-series dataset. For this analysis, each participant represents a cross-section of information and the monthly energy use representing the time-series of information. For this analysis, we specified the panel data models as random effects, which means that we explicitly attempt to account for (measureable) characteristics of each household assumed to be important in determining kWh use or natural gas consumption. An alternative approach, the fixed effects panel data model, explicitly accounts for idiosyncratic differences between each household by estimating a fixed y-intercept term for each household. (The fixed effects approach is the one we followed for the population model described above.)

Energy use is estimated as a function of numerous variables, including cooling degree days (evaporative cooler model), heating degree days (furnace and furnace-repair models), indicators for month, a variable representing time, indicator variable representing the months in which the LIEE measures were installed, and interaction terms between certain variables. Because the billing models control for month-to-month differences in outside temperature, characteristics of the households, seasonal effects, and the installation of other measures, statistically significant coefficient estimates for the variables representing the installation of evaporative coolers, furnaces, or furnace repair are interpreted as estimates of the actual change in energy use between the baseline and post-installation period.

The general form of the phone survey regression model is as follows:

[19] The study period would include the 12 or more months of billing data prior to installation of the LIEE measure and 12 or more months of billing data after installation of the LIEE measure. Household characteristics that may have changed during the study period include household size, changes in square feet of home, and other characteristics.

$$kWh_{it} = \beta_0 + \beta_1 Evap_{it} + \beta_2 CDD_{it} + \beta_3 Evap * CDD_{it} + \beta_4 Summer + \beta_5 TT_t + \beta_j HH_{j_{it}} + \beta_j OthMeas_{j_{it}} + \varepsilon_{it}$$

$Where:$

$kWh =$ Monthly electricity use in kWh (from billing system)

$Evap =$ Indicator variable for months in which the evap cooler from the LIEE program was installed

$CDD =$ Aggregate monthly cooling degree days (based on 65 degree ambient)

$TT =$ Time Trend; difference in days between Jan 1, 2007 and the monthly meter read date

$HH =$ House & Household specific characteristics (multiple variables)

$Summer =$ Indicator variable for months Jun through Sep

$OthMeas =$ Indicator variables for other measures installed through LIEE program

$i =$ index for household $(i = 1, ..., n)$

$t =$ Index for monthly time period $(t = 1, ..., 43)$

$j =$ index for household characteristics

$k =$ index for month $(k = 1(Jan), 2(Feb), ..., 11(Nov))$

$l =$ index for other measures installed

$\beta_0, \beta_1, ... =$ Coefficients to be estimated in the model

$\varepsilon =$ Random error term assummed normally distributed

The random-effects, panel data model specified for estimating the change in MCF of gas consumption associated with the installation of furnaces through the LIEE program is as follows:

$$therms_{it} = \alpha_0 + \alpha_1 Furn_{it} + \alpha_2 HDD_{it} + \alpha_3 Furn * HDD_{it} + \alpha_4 TT_t + \alpha_5 W + \alpha_j HH_{j_{it}} + \alpha_j Oth_{j_{it}} + + \alpha_j Oth_{j_{it}} * HDD_{it} + \upsilon_{it}$$

$Where:$

$therms =$ Monthly gas consumption in therms

$Furn =$ Indicator variable for months in which the Furnace measure from the LIEE program was installed

$HDD =$ Aggregate monthly heating degrees (based on 65 degree ambient)

$TT =$ Time Trend; difference in days between Jan 1, 2007 and the monthly gas read date

$HH =$ House & Household specific characteristics (multiple variables)

$W =$ Indicator variable for "winter" months Nov through March

$OthMeas =$ Indicator variables for other measures installed through LIEE program

$i =$ index for household $(i = 1, ..., n)$

$t =$ Index for monthly time period $(t = 1, ..., 43)$

$j =$ index for household characteristics

$k =$ index for month $(k = 1(Jan), 2(Feb), ..., 11(Nov))$

$l =$ index for other measures installed

$\alpha_0, \alpha_1, ... =$ Coefficients to be estimated in the model

$\upsilon =$ Random error term assummed normally distributed

The random-effects, panel data model specified for estimating the change in MCF of gas consumption associated with the furnace repair through the LIEE program is as follows:

$$therms_{it} = \lambda_0 + \lambda_1 Furn_{it} + \lambda_2 HDD_{it} + \lambda_3 Furnrep * HDD_{it} + \lambda_4 TT_t + \lambda_5 W + \lambda_j HH_{j_{it}} + \lambda_j Oth_{j_{it}} + + \lambda_j Oth_{j_{it}} * HDD_{it} + \upsilon_{it}$$

Where:

therms = *Monthly gas consumption in therms*

Furnrep = *Indicator variable for months in which the Furnace Repair measure from the LIEE program was installed*

HDD = *Aggregate monthly heating degree days (based on 65 degree ambient)*

TT = *Time Trend; difference in days between Jan 1, 2007 and the monthly gas read date*

HH = *House & Household specific characteristics (multiple variables)*

W = *Indicator variable for "winter" months Nov through March*

OthMeas = *Indicator variables for other measures installed through LIEE program*

i = *index for household* $(i = 1, ..., n)$

t = *Index for monthly time period* $(t = 1, ..., 43)$

j = *index for household characteristics*

k = *index for month* $(k = 1(Jan), 2(Feb), ..., 11(Nov))$

l = *index for other measures installed*

$\lambda_0, \lambda_1, ...$ = *Coefficients to be estimated in the model*

υ = *Random error term assummed normally distributed*

$$Therms_{it} = \lambda_0 + \lambda_1 FurnRep_{it} + \lambda_2 HDD_{it} + \lambda_3 FurnRep_{it} * HDD_{it} + \lambda_4 Days + \lambda_5 TT_t + \lambda_6 W_t + \lambda_j HH_{j_{it}} + \lambda_7 Oth_{it} + \lambda_8 Oth_{it} * HDD_{it} + \upsilon_{it}$$

Where:

Therms = *Monthly natural gas consumpion in therms*

Furn = *Indicator variable for in which furnace from LIEE program was installed*

HDD = *Aggregate monthly heating degrees (based on 65 degree ambient)*

Days = *Number of days in monthly billing cycle*

TT = *Time Trend; differene in days between jan 1, 2007 and the respective monthly gas read date*

W = *Indicator variable for "winter" months (Nov - Mar)*

HH = *House and household specific characteristics (multiple variables)*

Oth = *Indicator varible for any other EE measurs installed through LIEE program*

i = *index for household* $(i = 1, ..., n)$

t = *Index for monthly time period* $(t = 1, ..., 43)$

j = *index for household characteristics*

$\lambda_0, \lambda_1, ...$ = *Coefficients to be estimated*

υ = *Random error term assummed normally distributed*

4.3 On-Site Regression Model

The third regression model developed for this evaluation was the on-site regression model that relied on a smaller dataset of information collected during on-sites visits, combined with participant tracking and billing data for the on-site respondents. As discussed in the previous chapter, the on-site survey consisted of 400 site visits to homes and focused on participants that had either evaporative cooler or furnace replacement or repair conducted through program. Gas and electric models were constructed from these participants to try to refine the savings estimates for heating system repair and replacement and for evaporative coolers.

Some common elements between the electric and gas on-site models include the following:

- To estimate measure savings, the pre-installation period was defined as all activity prior to the installation of the measure and the post-installation period begins following the installation of the measure. The regression models contain one observation for billing cycle during the analysis period. The cross-section time series approach accounts 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.

- All measure variables were set to zero during the pre-period and one for the post-period. The electric model included monthly variables to account for the monthly variation in usage that was 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.

- All measures designed to save space heating energy use were modeled by estimating a constant heating coefficient over the entire analysis period and a separate heating coefficient for just the post-installation periods. This strategy allowed for the estimation of the change in heating for the group of homes receiving a specific measure or group of measures. The same approach was used for cooling-related measures in the electric model.

- The terms for space heating and cooling measures in the model were multiplied by average daily heating or cooling degree days. The resulting estimators were in units of kWh savings per degree day, and must be multiplied by the annual heating or cooling degree days for the participants with the measure to calculate energy savings per year.

- Only one heating or cooling-related measure was identified for each home, which helps reduce collinearity in the measure specifications as many households had multiple measures installed. In the gas 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 replacement was second, followed by heating system repair. 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. As discussed earlier, in the electric model, only evaporative cooler were targeted for the on-site sample.

- In some cases, small measures and/or common measures were combined into measure groups in order to be able to obtain reliable estimators. This approach was used in two specific situations: minor envelope/air sealing measures and the package of DHW conservation measures. For example, 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.

- The heating and cooling degree day variables in the regression model were calculated for each billing cycle. The utilities provided daily high and low temperatures from 2007 through 2010 by weather station, and these data were averaged and summed to obtain the heating and cooling degree days for each billing cycle. 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. All regression models included terms to control for temperature (heating and cooling degree days).

Additional details on the specifications for both the electric and gas on-site models are discussed below.

On-site Electric Model

The electric model included 234 homes and 174 homes with evaporative coolers. The general form of the fixed model was used, similar to the one described above for the population model. The variables included in the basic model are listed in Table 14. These variables were common to all of the candidate models. Refrigerator and DHW conservation measures were included in the model, although not used to estimate savings.

Table 14. Description of Common Variables in the Electric Model

Variable Name	Interaction	Measure Estimated	Meaning
amonth	None	None	Dummy variable for each month in the analysis period to account for the variation in use over time for all homes in the model
cWater	None	DHW Conservation Package	1 in the post period if any DHW conservation package measure was installed, 0 otherwise
ref	None	Refrigerator	1 in the post period if a refrigerator was installed in a home, 0 otherwise
nhdd/ncdd	None	Heating or Cooling Degree Days	Monthly heating or cooling degree days for the billing cycle for all homes in the model
Evap	ncdd	Evaporative Cooler	Cooling degree days in the post period if an evaporative cooler was installed, 0 otherwise
MaxEvap	ncdd	None	Cooling coefficient for all homes with evaporative cooler installations throughout the analysis period
Iclgnomeas	ncdd	None	Cooling coefficient for all homes with no cooling measures installed throughout the analysis period

In the candidate on-site models considered, homes with evaporative cooler installations were separated into various groups, and two additional variables were created for each group (one cooling variable for the post period only and a separate cooling variable for the entire analysis period). Table 15 shows the different combinations of models that were explored with a description of the various groups used for each.

Table 15. Description of Candidate Electric On-site Models

Description	Number of Groups	Group Definitions
Simple Model: Measures plus cooling variable for homes with A/C and no measures	None	
A/C Use during the pre-installation period	3	Central A/C use during the pre-period Room A/C use during the pre-period No A/C use during the pre-period
Reported change in A/C use between pre- and post-periods	4	A/C use same in pre- and post-periods A/C use somewhat less or a lot less in post-period No A/C in the post period Don't know/no answer/used more A/C in the post-period
Weather Zone Strata	2	Below 2,100 and above 2,100 annual CDD
Occupancy changes	3	Occupancy constant Increased occupancy in post-period Decreased occupancy in post-period
Window/wall area	4	Combined window/wall area Less than 1,264 square feet Greater than 1,264 and less than 1,448 Greater than 1,448 and less than 1,679 Over 1,678 square feet
Number of rooms cooled	5	Less than 3 rooms 3 to 4 rooms 5 to 6 rooms 7 or more rooms No answer
Age of Home	3	Home built before 1950 Home built between 1950 and 1979 (inclusive) Home built after 1980

On-site Gas Model

The on-site gas model included a sample of 242 homes, and the distribution of homes among the measures is provided in Table 16. There was a high degree of overlap of measure as most participants received more than one gas measure. As described above, only one measure was modeled for each home to limit collinearity across measures. The assignment of the home to a specific measure was conducted using a hierarchy according to the order of the measures as presented in the table. For example, a total of 59 homes received heating system replacements, but four (4) homes were already included in the insulation category, and thus there were 55 homes (59 - 4) in the model identified as replacing their heating systems. The most dramatic is weatherization, where almost all of the 229 homes also received at least one of the other measures. However, weatherization savings tend to be small, and thus the inclusion of weatherization with the other measures would not be expected to affect the results. The number of homes with the various gas measures is shown in Table 16.

Table 16. Distribution of Gas Measures

Measure	Total Number of Homes	Number of Homes with Measure in Model
Insulation	12	12
Heating System Replacement	59	55
Heating System Repair	133	122
Weatherization	229	35
None of above measures installed	18	18
Total		**242**

The variables included in the on-site gas model are described in Table 17, and these variables are common to all of the candidate models. The DHW conservation measures were also included in the model, although the model results were not used to estimate savings.

Table 17. Description of Gas Variables Used in the On-site Model

Variable Name	Interaction	Measure Estimated	Meaning
	None	None	Dummy variable for each year in the analysis period to account for the variation in use over time for all homes in the model
cWater	None	DHW Conservation Package	1 in the post period if any DHW conservation package measure was installed, 0 otherwise
cInsul	ncdd, has gas heat, heating system works	Insulation	Heating variable for all homes with insulation throughout the analysis period
cInsulpost	ncdd, has gas heat, heating system works	Insulation	Heating degree days in the post period if insulation was installed, 0 otherwise
cHSRepl	ncdd, has gas heat, heating system works	Heating System Replacement	Heating variable for all homes with heating system replacements throughout the analysis period
cHSReplpost	ncdd, has gas heat, heating system works	Heating System Replacement	Heating degree days in the post period if a new heating system was installed, 0 otherwise
cHSRpr	ncdd, has gas heat, heating system works	Heating System Repair	Heating variable for all homes with heating system repairs throughout the analysis period
cHSReplpost	ncdd, has gas heat, heating system works	Heating System Repair	Heating degree days in the post period if the heating system was repaired, 0 otherwise
cWx	ncdd, has gas heat, heating system works	Weatherization	Heating variable for all homes with weatherization measures throughout the analysis period
cWx	ncdd, has gas heat, heating system works	Weatherization	Heating degree days in the post period if weatherization measures were installed, 0 otherwise
Nomeasgas	Ncdd	None	Heating variable for all homes with working gas heat and no measures installed throughout the analysis period
Htgnowork	Ncdd	None	Heating variable for all homes marked as having gas heat but the heating system is not in working condition
Nogasheat	Ncdd	None	Weather effects for homes with no gas heat

A similar approach was used for the weather sensitive measures in the on-site models. Those homes with weather-sensitive measures were separated into various groups, and two additional variables were created for each group (a heating variable covering just the post period and the heating variable covering the entire analysis period) for each measure. Table 18 shows the different models that were tried with a description of the groups.

Table 18. Description of Candidate Gas On-site Models

Description	Number of Groups	Group Definitions
Simple Model: measures plus heating coefficient for homes with gas heat and no measures, non-working gas heat and weather effects for homes with no gas heat	None	
Gas use during the pre- and post-installation periods	2	Gas heat use during the pre- and post-installation periods Gas heat use only during the post-installation period (No homes were in the other cells)
Pre-installation heating use level estimated from the billing data	3	The model was run three times with different break points: 0.08, 0.12 and 0.18 therms/HDD. No savings were estimated for homes under these use levels.
Weather Zone Strata	2	Below 2,100 and above 2,100 annual HDD
Occupancy changes	3	Occupancy constant Increased occupancy in post-period Decreased occupancy in post-period
Window/wall area	4	Combined window/wall area Less than 1,264 square feet Greater than 1,264 and less than 1,448 Greater than 1,448 and less than 1,679 Over 1,678 square feet
Number of rooms heated	5	Less than 3 rooms 3 to 4 rooms 5 to 6 rooms 7 or more rooms No answer
Age of Home	3	Home built before 1950 Home built between 1950 and 1979 (inclusive) Home built after 1980

Model Selection

In the PY2009 LIEE Impact Evaluation, the information-theoretic approach to model selection based on Aikake's Information Criterion (AIC) was used, as it was in the previous PY2005 impact evaluation. The AIC approach provides an objective method to determine the best model out of the range of alternative and is designed to allow comparisons across a group of candidate models. The candidate models must have the same number of observations and a similar structure in order to use the AIC. Models in which the dependent variable is transformed or that assume a lognormal distribution of errors, for example, cannot be compared with untransformed models

The AIC is largely based on model fit, and balances number of additional variables introduced with the improvement in model fit. The approach was to apply the model selection in two stages, with the first stage comparing broad strategies for modeling weather-sensitive impacts and other large-scale effects, and the second stage for refining the models. The model with the lowest AIC value is interpreted as the one that best fits the data set, *i.e.*, the model that minimizes the information loss.

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

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

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.

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

$$\Delta_i = \mathrm{AIC_i} - \min(\mathrm{AIC}) \ ,$$

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. However, these ground rules presume that all of the basic assumptions of linear regression are met.

The lessons learned in model selection and applying the AIC from the PY2005 impact evaluation modeling were applied to this analysis. The process of using the survey data (on-site and telephone data) to refine the models involved developing potential hypotheses about the explanatory value of the variables and then constructing the models accordingly. The success of the process is related partially to the model fit, but also the ability of the resulting estimators to effectively explain the differences in savings. However, the model with the best fit does not always result in useful results. For example, a model may improve the fit but also include variables that exhibit collinearity and/or produce coefficient estimates that have the wrong sign. For this reason, a combination of the model fit and the validity of the estimators were used to select the final models used to calculate impacts.

CHAPTER 5: MODEL ESTIMATES TO IMPACTS

5.1 POPULATION IMPACT ESTIMATION

As discussed in the prior chapter, the results of the population model were selected as the best available estimates from the different models explored in this evaluation. This chapter discusses how the results of that model were used to calculate kWh, kW, and therm impacts for the 2009 LIEE program and follows closely the method used in the PY2005 LIEE impact evaluation. Where possible, these impacts are calculated at the measure level, by house type and by climate zone, for each utility.

Regression Output to Impact Estimates

The regression coefficients are all estimated in terms of monthly kWh or therms, and a number of steps were taken to adjust the regression output to obtain savings estimates. The approach varied according to the measure and the characteristics of the regression coefficient. The variety of strategies used can be divided into four categories, from the simplest to the most complex:

1. Non-weather sensitive (base) measures estimated by a single dummy variable

2. Base measures estimated by use level

3. Weather sensitive measures estimated by climate zone

4. Weather sensitive measures estimated by use level

The procedures associated with each of these sets of measures are described in more detail below.

Base Measures

Single Estimators

The regression coefficients for lighting, the DHW package in the electric model and the DHW replacement in the gas model were developed from a single dummy variable. In this case, the savings estimates are simply the regression coefficient (monthly kWh) times the 12 months in a year.

Estimators by Use Level

The savings for refrigerator replacements and the DHW package in the gas model were estimated by use level. In this case, the savings are the weighted average, calculated to account for the percentage of homes in each use level. An example is provided below for estimating refrigerator savings from the electric model. As can be seen from Table 19, the average savings for refrigerators comes to 740 kWh.

Table 19. Refrigerator Savings from the Electric Model (Single Family Homes)

Use Level	Number of Homes in the Model	Percent of Homes in the Model	Savings from the Model (kWh)	Prorated Savings (kWh)
1	350	5%	184	9
2	2,413	36%	476	169
3	3,144	46%	828	381
4	912	13%	1,346	180
Totals	**6,819**			**740**

When these estimates were applied to the entire population of LIEE participants, the distribution of participants among the use levels was assumed to be the same as for those accounts included in the regression models. The same process of using weighted averages from the homes in the models was used to estimate savings by house type, as discussed below.

Weather-Sensitive Measures

All weather sensitive measures were modeled by estimating the heating coefficients separately for the pre- and post-installation periods and comparing them to estimate the change in the heating or cooling coefficient. The regression coefficients for the weather sensitive measures were estimated in terms of kWh per heating or cooling degree day and must be adjusted to calculate annual kWh savings.

Estimated by Climate Zone

The savings for the air sealing and minor envelope measures in the gas model were estimated separately for each of the 16 CEC climate zones and the final savings were calculated as a weighted average over all climate zones. To estimate the weighted average savings per household, the regression coefficients for each climate zone were multiplied by the sum of the heating degree days for that climate zone. These values were then summed and divided by the total number of participants who received the measure.

This same process was applied to the total LIEE population when calculating the final program savings. The ten-year normalized degree days were used when calculating the total program savings for weather sensitive measures. The savings by house type reflect the weather-specific conditions for the subset of participants with the measure.

Estimated by Use Level

Attic insulation cooling savings in the electric model and attic insulation and heating system repair and replacement savings in the gas model were estimated by use level. Breaking out the savings by use level provided us with sufficient information to estimate savings by housing type and utility as well as accounting for weather variations.

The method used for estimating the gas savings from attic insulation is illustrated below. For this measure, installations were made in both single family and multifamily buildings. The steps are as follows:

1. Count the number of accounts and sum the heating degree days by multifamily and single family homes and by use level for all accounts included in the model.

2. Calculate the weighted average of the change in the heating coefficient by housing type using the estimators from the regression model and the distribution of the accounts included in the model.

3. Count the number of accounts and sum the heating degree days by multifamily and single family homes and by utility for all LIEE PY2009 participants with this measure.

4. Apply the blended (weighted average) change in the heating coefficient estimate from Step 2 to the heating degree days from Step 3 by utility and house type to estimate savings for the total population of LIEE PY2009 participants by utility and house type.

Table 20. Attic Insulation Heating Parameter Estimates

House Type	Use Level	Counts	Estimated Change in Heating (Therms/HDD)	Average HDD	Savings per Home (Therms)	Total Savings (Therms)	Total HDD
MF	1	17	-0.0047	1,268	-5.9	-101	21,555
	2	40	-0.0001	1,547	-0.2	-8	61,891
	3	23	0.0098	1,344	13.1	302	30,923
	4	6	0.0101	1,182	12.0	72	7,090
	Totals	**86**		**5,341**		**265**	**121,459**
SF	1	52	-0.0047	1,975	-9.2	-480	102,679
	2	756	-0.0001	1,802	-0.2	-180	1,362,360
	3	1,132	0.0098	1,549	15.1	17,142	1,753,762
	4	378	0.0101	1,195	12.1	4,569	451,591
	Totals	**2,318**		**6,521**		**21,051**	**3,670,392**

MF Blended Change in Heating: Total Savings/Total HDD = 265 / 121,459

= 0.002182 therms/HDD

SF Blended Change in Heating: 21,051 / 3,670,392 = 0.005735 therms/HDD

Estimating Savings by Housing Type

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. In general, multifamily homes tend to use less electricity than single family, and mobile homes often consume more. Thus, estimating savings by use level offers an innovative approach to estimating savings by housing type. Since the savings for some measures were not estimated by use level, alternative strategies were also adopted as needed.

Two approaches were used to estimate savings by house type:

1. For measures estimated by use level, the distribution of homes in each housing type among the use levels was used to break out the savings by housing type.

2. For measures that were not estimated by use level, no attempt was made to develop estimates by housing type.

Each measure is categorized accordingly in Table 21 below. For some weather sensitive measures estimated by use level, the sample sizes within a specific use level and housing type were insufficient to estimate savings and approach 2) was applied as necessary.

Table 21. Summary of Measures and Method of Estimating Savings by House Type

Weather Sensitive Measures		Base Measures	
Estimated by Use Level	**Not Estimated by Use Level**	**Estimated by Use Level**	**Not Estimated by Use Level**
Attic Insulation (gas) Heating System Repair and Replacement (gas) Attic Insulation Cooling (electric) Evaporative Coolers (electric) Efficient Room A/C (electric)	(None)	DHW Conservation (gas) Refrigerators (electric)	DHW Replacement (gas) Lighting (electric) DHW Conservation (electric)

5.2 Demand Impacts

In addition to estimating kWh and therm impacts, the evaluation was also tasked with estimating the kW demand impacts for LIEE measures. Extensive work was one in the PY2005 LIEE impact evaluation to develop a method of converting kWh impacts to kW impacts using coincident peak factors from the DEER database. These same conversation factors are applied in the PY2009 evaluation to leverage the work completed and vetted in the prior LIEE impact evaluation.

A critical part of this task was to match up the LIEE measures to those in the DEER database. For the purposes of determining coincident peak load factors, the primary issue is to find a measure with the same load profile. Since the ratio of the KW demand to kWh savings is of primary interest, the actual values of the numerator and denominator are not of central importance. An illustration of this point is that the ratio of coincident peak reduction (KW) to energy savings (kWh) for low flow showerheads, aerators and high efficiency water heaters in the DEER database are the same, despite the fact that the respective values used in the numerators and denominators are different.

Some of the underlying assumptions behind the load profile, however, may affect coincident peak savings and should be considered. To take lighting as an example, the load profile is based on assumed values of the reduction in Watts and the hours of use. DEER has three sets of CFL measures will different assumptions regarding the hours of use (.5, 2.5 and 6 hours per day). The daily usage patterns will affect the likelihood that energy will be saved during the coincident peak. For CFL's, we selected the measure based on 2.5 hours per day, since that is the closest value to the average 2.9 hours per day for LIEE participants as estimated through the on-site survey from the PY2005 evaluation. (Note that we did not attempt to collect new operating hour data for CFLs as part of the PY2009 on-sites).

Additionally, the DEER measures are not specific to the low-income sector, and it is theoretically possible that there are differences in the daily pattern of energy use between the general residential and low-income markets. One known way in which the low-income sector is different from the overall residential population is that low-income households tend to use less energy on average. However, this effect is incorporated into the energy savings and, by extension, is taken into account in the estimation of the coincident peak demand savings. The remaining question is whether low-income households use energy at different times of the day in comparison to other residential households. At this point, we do not know of any definitive research to provide guidance in this area.

The remainder of this section covers the definition of the peak period and the estimation of the coincident peak demand factors for base and weather sensitive measures, respectively.

Definition of the Peak Period

Our definition for the peak period for weather sensitive measures is taken from the supplemental documentation for the 2004-2005 DEER update: "[t]he DEER demand impact is defined as the average demand impact, for an installed measure, as would be 'seen' at the electric grid level, averaged over the nine hours, between 2 PM and 5 PM, during the three consecutive weekday period [*sic*] which contains the weekday with the highest temperature of the year."[20]

For the base (non-weather sensitive measures), the definition of the peak period is defined as the average demand savings between noon and 6 PM for the six months from May to October. When the DEER update was done in March of 2006, there was insufficient data to update these coincident peak demand savings.[21] Since the peak period is defined by the hottest weather and the savings for these base load measures are likely remain relatively consistent over this period, the older definition seems sufficient for our purposes.

Coincident Peak Factors for Base Measures

For base measures, the coincident peak savings are estimated directly from the load profiles found in the CEC's peak demand forecasting model.[22] For the base measures, the ratio of the coincident peak reduction to energy savings is consistent over all house types, all measure definitions within the end use (except as specified for the CFL's) and all climate zones. The ratio is the same for low flow showerheads, aerators and high efficiency water heaters, indicating that this value is appropriate to apply to the entire DHW conservation package. The DEER database includes both new refrigerators and refrigerator/freezer recycling, but the coincident peak demand factor is the same for all refrigerator measures.[23]

The coincident peak demand to energy savings ratios for the base measures are presented in Table 22.

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[20] James J. Hirsch and Associates, "Definition of Demand (kW) Impacts Used in the 2005 DEER Update", March 21, 2006, corrected March 24, 2006. Page 1.

[21] *Ibid.*, page 1.

[22] Itron, "2004-2005 Database for Energy Efficiency Resources (DEER) Update Study Final Report," prepared for Southern California Edison. December, 2005. Page 2-2.

[23] *Ibid.*, page 2-8.

Table 22. DEER Coincident Peak Factors for Base Measures

DEER Measure ID	DEER Description	LIEE Measure	DEER Above Code Electricity Savings (kWh/ unit)	DEER Above Code Peak Demand Impact (Watts/ unit)	DEER Coinci-dent Peak Factor (KW/ kWh)
D03-801	13 Watt < 800 Lumens - screw-in Replaces: 40W Incandescent	Lighting - CFL's	21	2	0.00011
D03-957	Refrigerator: Top Mount Freezer	Refrigerator Replacement	47	8	0.00017
D03-937	Low Flow Showerhead	DHW Conservation Package	133	29	0.00022

Coincident Peak Factors for Weather-Sensitive Measures

For the weather sensitive measures, the peak load savings in the DEER database are estimated from DOE-2 simulations.[24] Since the coincident peak occurs near the hottest day of the year and space heating is not needed in the extreme hot weather, there are no coincident peak demand savings for measures that are targeted to save electric space heating, such as air sealing/minor envelope measures and the heating component of attic insulation. Cooling measures would be expected to be in use during the coincident peak period, and coincident peak ratios were estimated for these measures.

There are a number of issues that arose in the process of applying the DEER weather sensitive measures to the LIEE Program, as described below.

- The evaporative cooler measure in DEER assumes that the evaporative cooler completely replaces the refrigerant-based air conditioning load. In contrast, the LIEE protocols only allow the installation of an evaporative cooler in homes with a refrigerant-based air conditioning system. This difference in approach could have a substantial impact on the coincident peak reduction, given that the most extreme hot weather will be exactly when the LIEE participants are the most likely to revert to using their refrigerant-based air conditioners and the DEER database modeling assumes that there will be no air conditioning load in these homes.

  The question arises whether there are any coincident peak savings in these homes. The phone survey provides some information that sheds light on this issue. This survey indicates that 22% of LIEE participants who received evaporative coolers do not use their air conditioning at all or no longer have a working air conditioner. Thus, we can assume that the full coincident peak ratio as found in the DEER database can be applied to 22% of the LIEE homes with evaporative cooler installations. In the absence of other information, no coincident peak savings were estimated for the other 78% of homes who received evaporative coolers through LIEE.

- The DEER database has A/C efficiency improvements for central A/C only, but the LIEE program installs efficient room air conditioners. This issue is less problematic. The room air conditioners

[24] *Ibid*., page 5-1.

only cool part of the home, resulting in both lower energy savings and lower coincident peak reduction. Therefore, we applied the DEER KW/kWh ratio to the relatively low LIEE savings estimates.

- DEER separates measures by housing type, the vintage of the housing stock and climate zone. The KW/kWh ratios for base measures do not vary across these three factors, but the ratios do vary for the weather sensitive measures. For the LIEE participants with weather sensitive measures, we know the climate and housing type but we have no information regarding the age of the homes. Accordingly, we selected DEER characterizations for housing stock that is at least twelve years old, and calculated a simple average of the KW/kWh ratios for the pre-1995 categories. The ratios of KW/kWh tended to be quite close, so the averaging may have been unnecessary.

- For attic insulation, the DEER database lists three measures: adding insulation up to a total of R-30, R-38 or R-49 to an uninsulated home. According to the LIEE P&P manual, the program offers to add insulation up to R-30 for homes with R-11 or less in most of the CEC climate zones. However, the peak impact fields in the DEER database were empty for the DEER R-30 measure for the warmer climate zones and entered in the cooler climate zones, which seems counterintuitive. Consequently, we estimated the savings for the measure characterized as adding insulation up to a total of R-38 to an uninsulated home, where DEER database values were complete. These numbers are small and will not have a noticeable impact on program savings.

Table 23 below gives the coincident peak factors by climate zone and house type for the weather sensitive measures. There were no installations of attic insulation in mobile homes, so it was unnecessary to estimate the peak factors for this house type. For climate zones 1-4 and 6-7, the coincident peak factors from climate zone 16 were used, which had the most similar weather characteristics.

Table 23. DEER Coincident Peak Factors for Weather-Sensitive Measures

House Type	Climate Zone	Coincident Peak Demand Factors (KW/kWh)			
		Evap Cooler	LIEE Adjusted Evap Cooler	Room A/C	Attic Insulation
MF	1	0.0018	0.0004	0.0035	0.0007
MF	2	0.0018	0.0004	0.0035	0.0007
MF	3	0.0018	0.0004	0.0035	0.0007
MF	4	0.0018	0.0004	0.0035	0.0007
MF	6	0.0018	0.0004	0.0035	0.0007
MF	7	0.0018	0.0004	0.0035	0.0007
MF	9	0.0015	0.0003	0.0017	0.0003
MF	10	0.0017	0.0004	0.0015	0.0009
MF	11	0.0020	0.0004	0.0017	0.0007
MF	12	0.0012	0.0003	0.0019	0.0003
MF	13	0.0015	0.0003	0.0011	0.0004
MF	14	0.0008	0.0002	0.0014	0.0002
MF	15	0.0043	0.0009	0.0007	0.0014
MF	16	0.0018	0.0004	0.0035	0.0007

MH	9	0.0021	0.0005	0.0026	
MH	10	0.0026	0.0006	0.0020	
MH	11	0.0031	0.0007	0.0020	
MH	12	0.0018	0.0004	0.0026	
MH	13	0.0021	0.0005	0.0015	
MH	14	0.0010	0.0002	0.0015	
MH	15	0.0110	0.0024	0.0008	
MH	16	0.0027	0.0006	0.0052	
SF	1	0.0016	0.0004	0.0042	0.0005
SF	2	0.0016	0.0004	0.0042	0.0005
SF	3	0.0016	0.0004	0.0042	0.0005
SF	4	0.0016	0.0004	0.0042	0.0005
SF	6	0.0016	0.0004	0.0042	0.0005
SF	7	0.0016	0.0004	0.0042	0.0005
SF	9	0.0014	0.0003	0.0014	0.0005
SF	10	0.0016	0.0004	0.0013	0.0007
SF	11	0.0020	0.0004	0.0013	0.0008
SF	12	0.0012	0.0003	0.0016	0.0003
SF	13	0.0017	0.0004	0.0009	0.0007
SF	14	0.0009	0.0002	0.0013	0.0003
SF	15	0.0076	0.0017	0.0006	0.0013
SF	16	0.0016	0.0004	0.0042	0.0005

CHAPTER 6: TELEPHONE AND ON-SITE SURVEY RESULTS

This chapter describes the households that participated in the LIEE program and their energy consumption habits. The first section discusses data collected from the phone survey and the second section discusses the on-site surveys.

6.1 PHONE SURVEY RESULTS

As described in Chapter 3, the evaluation team developed a stratified random sample of LIEE participants, with a focus on selected measures where we believed that additional phone survey information may help develop more robust billing regression model estimates of impacts.[25] The primary purpose of this survey was to collect information on household energy use, demographics, and changes in the household or home that may affect the billing model. Selected survey results are presented below with full survey results included in Appendix A. Note that a similar survey was also fielded for a control group of non-participants and these results were also used in the billing regression model.

Table 24. Distribution of IOUs in Survey Sample

	Surveyed Households	
	Number	**Percent**
PG&E	585	39%
SCE	358	24%
SCG	456	30%
SDG&E	103	7%
Total	**1502**	**100%**

Household Characteristics

The sample for the telephone survey was over-sampled for households that had received evaporative coolers, furnaces, furnace repair, and/or weatherization measures. Table 25 shows the distribution of respondents across the targeted measures. Note that since some respondents had more than one of the targeted measures, the sum of households in Table 25 is greater than the number of households surveyed.

[25] The sample had 11 strata, based on the measure the household received and climate zone, and the survey results presented below have been weighted by these strata.

Table 25. Distribution of Measures in Survey Sample

	Surveyed Households	
	Number	Percent
Evaporative Cooler	376	25%
Furnace	447	30%
Furnace Repair	310	21%
Weatherization	652	43%
Total households surveyed	**1502**	**100%**

Note: Sum of surveyed households exceeds total due to some households having more than one of the targeted measures.

Table 26 shows the portion of participants (by targeted measure) that own or rent. Homeowners make up the majority of participants at 70 percent overall. Almost all households that received a furnace or furnace repairs owned their homes, while a slightly smaller portion of households that received an evaporative cooler owned their homes. The households that received weatherization as their primary measure were less likely to be homeowners.

Table 26. Home Ownership

	Evaporative Cooler	Furnace	Furnace Repair	Weatherization Only	Total
Own	90%	97%	92%	65%	70%
Rent	10%	3%	8%	35%	30%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

The survey asked LIEE participants about the size of their homes. Only about three-quarters of the sample household were able to report the size of their home. Most of the LIEE participants live in homes smaller than 1,500 square feet (see Table 27).

Table 27. Size of Home

Size of Home	Percent
Less than 1,000 square feet	31%
Between 1,000 and 1,500 square feet	40%
Between 1,500 and 2,000 square feet	20%
Greater than 2,000 square feet	8%
Total	**100%**

Households participating in LIEE tend to be smaller and older than the typical California household, according to the U.S. Census (see Table 28). Half of the LIEE households include at least one elderly resident and about one-quarter of the LIEE households are solely occupied by individuals older than 65.

Table 28. Household Size and Portion with Senior Citizens

	LIEE Households	California
Average Household Size	2.35	2.92
Households with one or more people 65 years and over	50%	23%

California data from U.S. Census, 2006-2008 American Community Survey (http://factfinder.census.gov).

As shown in Table 29, 90 percent of households reported a combined household income less than $50,000 and over half reported a household income less than $25,000.

Table 29. Gross Annual Income by Household Size

	Size of Household				
	1	**2**	**3-4**	**5+**	**Total**
Less than $25,000	83%	56%	41%	39%	59%
Between $25,000 and $50,000	7%	33%	43%	38%	28%
Between $50,000 and $100,000	2%	1%	8%	23%	5%
More than $100,000	0%	1%	0%	0%	1%
Refused/Don't Know	8%	9%	8%	1%	8%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

Evaporative Coolers

Respondents that had received an evaporative cooler (376 in the survey sample) were asked questions regarding the cooling equipment installed in their household. As shown in Table 30, the vast majority of evaporative coolers were still installed and functioning for these customers.

Table 30. Is the Evaporative Cooler Still Installed and Working?

Evaporative cooler still installed and working?	Yes	No	Don't Know
Still installed	97%	3%	0%
Still installed and working	94%	5%	1%

Of the ten households that reported the evaporative cooler was no longer installed, the majority (six households) said it was not working. One respondent reported they had moved from that residence, one had installed new windows and the cooler had been removed to accommodate the new windows, and two households reported they had put the cooler away for the winter and the weather had not yet been hot enough to use the cooler.

The survey asked recipients of new evaporative coolers if the new cooler replaced an old cooling system or if it was a new addition to their home. For most households (83 percent), the cooler was a new addition. For those households that replaced an older cooling system with the new evaporative cooler, almost two-thirds replaced an air-conditioner (see Table 31).

Table 31. Type of Cooling System Evaporative Cooler Replaced

New Addition or Replacement	Percent
New addition to home	83%
Replaced old system	17%
What kind of cooling system did the evaporative cooler replace?	
Central air conditioning	35%
Individual room air conditioners	24%
Evaporative cooler	40%

Two-thirds of the recipients of new evaporative coolers reported that there was some other kind of cooling system in their home, as shown in Table 32. The table also shows the types of cooling systems that are also present in the homes that received an evaporative cooler. Almost all of the homes with some kind of functioning cooling system have air conditioning.

Table 32. Other Types of Operating Cooling Equipment

Type of cooling equipment in the home, in addition to evaporative cooler	Percent
Central air conditioning with ducts	55%
Room air conditioning	6%
Room ceiling fans	1%
Stand-along fans	2%
Evaporative cooler	1%
No other cooling equipment in home	34%

Respondents were also asked if their air conditioning use had changed at all with the installation of the evaporative cooler. Table 33 shows that that most of these households—over three-quarters—have greatly decreased their use of their air conditioners.

Table 33. Air Conditioner Use Since Installation of Evaporative Cooler

Has your use of your air conditioner changed since the evaporative cooler was installed?	Percent
Do not use AC at all anymore	29%
Use AC a lot less than I used to	49%
Use AC somewhat less than I used to	15%
Use AC about the same as I used to	7%
Use AC more than I used to	<1%

Table 34 shows the number of days per year the respondents reported they had used their evaporative cooler. The table shows the portion of respondents by climate, broken into two basic cooling climate categories: the less severe cooling climate where the number of cooling degree days (CDD) is less than 2,100, and the more severe cooling climate where there are more than 2,100 CDD. The data show that the coolers are well used by the recipients in both climate categories. The households in the less severe cooling climate tended to use the evaporative coolers more days per year, with 58 percent of those households using the coolers more than 61 days per year, compared to 50 percent of the households in the hotter climates. This may be because the households in the hotter climates may feel the need to rely on air conditioners on very hot days. Overall, there is a high use of evaporative coolers among those surveyed. This relatively high use is consistent with the decreased use of other air conditioning equipment discussed above and suggests that the evaporative cooler is being used to meet a significant portion (if not all) of the cooling demand in these homes.

Table 34. Evaporative Cooler Usage

	Recipients of an Evaporative Cooler		
Days per Year	**All Respondents n=340**	**<2,100 CDD n=314**	**>2,100 CDD n=26**
Not at all	1%	1%	0%
10 days or less	4%	4%	8%
11-30 days	15%	15%	19%
31-60 days	22%	22%	23%
61-90 days	28%	29%	19%
More than 90 days	29%	29%	31%

The survey asked the households how often they ran the air conditioning with the evaporative cooler turned off. Almost half (46 percent) they never do and the same portion reported they sometimes do. Only a small portion of these households (eight percent) reported that they always run the air conditioner when the evaporative cooler is turned off.

The survey asked households how often they operate their new evaporative cooler with the windows open, as a steady flow of outside air is needed to maximize the operation of the evaporative cooler.[26] As shown in Table 35, a significant portion of these households (25 percent) reported they never open the windows when operating the cooler, while an additional 19 percent said that they only sometimes have the windows open when the cooler is operating. These households are not maximizing the cooling potential of the equipment. These results indicate that the LIEE program should expand its efforts to teach recipients how to properly use the equipment thereby reducing their electricity bills and making their homes more comfortable.

Table 35. Frequency Household Operates Evaporative Cooler with Window Open

Frequency	Percent
Always	57%
Sometimes	19%
Never	25%

[26] Evaporative coolers work by pulling air over a wet pad, and the water cools the air down. To direct the cooled air through the house, a window should be opened to pull the cooled air through the house.

It is clear that the evaporative cooler program is replacing the use of air conditioners in a majority of households surveyed. For a small portion of homes, the cooler has physically replaced an older piece of equipment. For the homes that have both air conditioning and a new cooler, the households are choosing to operate the cooler instead of the air conditioner. About two-thirds of homes with both forms of cooling equipment have greatly reduced their use of the air conditioner, and over 90 percent have reduced the use of the air conditioner to some degree. However, a significant number of households surveyed indicated that they never open a window when operating the evaporative cooler—a step that improves the airflow and functionality of the cooler. This suggests that the LIEE program should place more emphasis on explaining how to best operate the coolers to the participants.

Finally, a series of questions were asked to gauge how likely these households would have been to purchase an evaporative cooler without the LIEE program. Respondents were asked about the likelihood of purchasing an evaporative cooler outside the program as well as the estimated timing of the purchase. The combined results of these questions are shown in Table 36.

From these responses, about a third (30 percent) stated that they were very or extremely likely to have purchased an evaporative cooler without the LIEE program. About half (54 percent) stated they were not very or not at all likely to have purchased a cooler without the program. The table also shows the estimated time frame they would have purchased the cooler in the absence of the LIEE program. Very few households (nine percent) reported the purchase would have occurred at the same time. The majority of the households would have delayed the purchase more than a year. The LIEE program assumes there is no free ridership for the measures, but these results indicate there is some free ridership occurring even at the very low-income levels eligible for the LIEE program. The estimated timing of the purchase indicates that very few households had real plans to purchase an evaporative cooler in the immediate future.

Table 36. Likelihood of Purchasing an Evaporative Cooler Without the LIEE Program

Likelihood of household to purchase evaporative cooler without LIEE Program		Estimated timing of purchase without LIEE Program: At the Same Time	Within a Year	More than a Year	Don't Know/ Refused	Total
Extremely Likely	11%	0%	27%	68%	5%	100%
Very likely	19%	14%	28%	50%	8%	100%
Somewhat likely	16%					
Not very likely	26%					
Not at all likely	29%					
Total	**100%**	**9%**	**28%**	**57%**	**7%**	**100%**

Furnace Replacement

The phone survey included 447 households that received a new furnace through the LIEE program. Of these, the survey confirmed that 99 percent of those households still had the furnace installed and that 96 percent of these furnaces were still operating (see Table 37). The one household that reported the furnace was no longer installed indicated it was removed because it was no longer working.

Table 37. Is the New Furnace Still Installed and Working?

Furnace still installed and working?	Yes	No	Don't Know
Still installed	99%	0%	0%
Still installed and working	96%	3%	1%

The survey asked the recipients of a new furnace what had been their primary source of heat before the new furnace was installed. Table 38 shows that most of the recipients (76 percent) replaced an existing furnace. A small portion (nine percent total) used a fireplace or wood-burning stove or they had no heat source at all. It is not likely that 45% of the homes had electric forced air systems, as that configuration is rare. The identification of the heating system may be one area where on-sites are needed if reliable data is to be collected.

Table 38. Primary Source of Heat before New Furnace Was Installed

Primary Heat Source	Percent
Gas furnace or other gas heater	31%
Electric forced air furnace	45%
Electric heat pump	1%
Electric space heater	7%
Unspecified electric heat	4%
Fireplace/Wood-burning stove	1%
Nothing/Non-operating equipment	8%
Refused/Don't Know	3%

The survey asked recipients of new furnaces if the new furnace replaced an old system or if it was a new addition to their home. For most households (89 percent), the furnace replaced an old system (see Table 39).

Table 39. Was New Furnace a New Addition or Replacement of Existing System?

New Addition or Replacement	Percent
New addition to home	11%
Replaced old system	89%

For those households that replaced an older heating system with the new furnace, the survey asked if the old system was working and what type of system it was. Table 40 shows that most of the households replaced an existing furnace system (93 percent). The table also shows that the majority of households replaced a heat source that was not working. Across heating types, 65 percent replaced a broken heating system. These results suggest that these LIEE households are likely to see an increase in energy consumption as they start using their heating systems.

Table 40. Type of Heating System New Furnace Replaced and Was Old System Working

	Percent of all Heating Types	Was Old System Working? (Percent of each Heating Type)	
		Yes	No
Gas furnace or other gas heater	41%	37%	63%
Electric forced air furnace	52%	36%	64%
Other electric heat	5%	24%	76%
Refused/Don't Know	2%	13%	88%
Total	**100%**	**35%**	**65%**

The evaluation team wanted to know if households had changed the way they heated their homes after installing the new furnace. Table 41 shows that most of the households that had their furnace replaced now use their furnace more or the same amount as they did before participating in the LIEE program. This self-reported estimate of use suggests that savings will be limited from this measure.

Table 41. Change in Use of Furnace

Have you changed your use of your heating systems since the new furnace was installed?	Percent
Used the previous system less	33%
Used the previous system about the same	50%
Used the previous system more	17%

Table 42 shows the number of days per year the respondents reported they had used their new furnace. The table shows the portion of respondents by climate, broken into two basic heating climate categories: the less severe heating climate where the number of heating degree days (HDD) is less than 2,100, and the more severe heating climate where there are more than 2,100 HDD. The data show that, overall, the new furnaces are not heavily used. About 60 percent of the responding households reported using the new furnaces less than 61 days per year. However, in the more severe climate, 63 percent of the households use the new furnaces more than 60 days per year, compared to 34% of households in the less severe climate.

Table 42. Days per Year Households Used New Furnace

	Recipients of a New Furnace		
Days per Year	All Respondents n=388	<2,100 HDD n=298	>2,100 HDD n=90
Not at all	2%	2%	2%
10 days or less	12%	14%	6%
11-30 days	22%	25%	12%
31-60 days	22%	24%	17%
61-90 days	16%	16%	17%
More than 90 days	24%	47%	18%

As with the other measures, as series of self-reported free ridership questions were asked regarding new furnaces. Respondents that received a new furnace were asked if they would have purchased the furnace without the LIEE program and the timing of their purchase. As shown in Table 43, 26 percent were extremely or very likely to purchase a new furnace in absence of the LIEE program. Of these, 58 percent reported they would have made the purchase at the same time or within a year.

Table 43. Likelihood of Purchasing Furnace without LIEE Program

Likelihood of household to purchase furnace without LIEE Program		Estimated timing of purchase without LIEE Program: At the Same Time	Within a Year	More than a Year	Don't Know/ Refused	Total
Extremely Likely	12%	26%	42%	20%	12%	100%
Very likely	14%	10%	40%	36%	14%	100%
Somewhat likely	16%					
Not very likely	22%					
Not at all likely	37%					
Total	**100%**	**18%**	**41%**	**29%**	**13%**	**100%**

Furnace Repair

A parallel set of questions was asked of those respondents receiving furnace repair through the LIEE program. Of the 310 respondents that received furnace repair, 99 percent indicated that their furnace was still installed and 83 percent said that the furnace was still operating after the repairs (see Table 44).

Table 44. Is the Repaired Furnace Still Installed and Working?

Furnace still installed and working?	Yes	No	Don't Know
Still installed	99%	1%	0%
Still installed and working	83%	14%	3%

Four households reported that the repaired furnace was no longer installed. All those households reported the furnace had been removed because it was no longer working.

Furnace repair recipients were also asked if their heating system use changed since the furnace repair. Table 45 shows that most of the households that had their furnace repaired now use their furnace more or the same amount as they did before participating in the LIEE program. As with the furnace replacement, the increased use of the furnace after the repair will likely limit the amount of savings observed for this measure.

Table 45. Change in Use of Repaired Furnace

Have you changed your use of your heating systems since the furnace was repaired?	Percent
Used the furnace less before it was repaired	28%
Used the furnace about the same before it was repaired	55%
Used the furnace more before it was repaired	17%

Table 46 shows the number of days per year the respondents reported they had used their repaired furnace. The table shows the portion of respondents by climate, broken into two basic heating climate categories: the less severe heating climate where the number of heating degree days (HDD) is less than 2,100, and the more severe heating climate where there are more than 2,100 HDD. The data show that, overall, the repaired furnaces are not heavily used. Only 30 percent of the households reported using their repaired furnaces more than 61 days per year. Households in the colder climates reported more frequent use, with 38 percent using the repaired furnace more than 61 days per year.

Table 46. Days per Year Households Used Repaired Furnace

	Recipients of a Repaired Furnace		
Days per Year	**All Respondents n=388**	**<2,100 HDD n=152**	**>2,100 HDD n=124**
Not at all	14%	15%	13%
10 days or less	16%	17%	15%
11-30 days	21%	22%	20%
31-60 days	18%	22%	14%
61-90 days	12%	12%	13%
More than 90 days	18%	12%	25%

The self-reported results from the survey suggest that savings will be limited from this measure. Over two-third of the households use their furnace fewer than 60 days a year and 14 percent reported not using the repaired furnace at all. In climate zones with colder winters, a furnace will be used more often, so an efficient furnace will be used more days a year, offering a larger savings increment. In the relatively mild climate zones in the IOUs' service area, furnaces are not used that frequently.

The same free ridership question battery was asked of furnace repair recipients regarding the likelihood and timing of repairing the furnace outside the LIEE program. The combined results are shown in Table 47. About a third of these respondents indicated that they were extremely or very likely to do the furnace repair in absence of the program, which is similar to the responses received for the other measures. Of these, 48 percent indicated that they would have done the repair at the same time or within the year.

Table 47. Likelihood of Household to Repair Furnace without LIEE Program

Likelihood of household to repair furnace without LIEE Program		Estimated timing of repair without LIEE Program				
		At the Same Time	Within a Year	More than a Year	Don't Know/ Refused	Total
Extremely Likely	10%	26%	42%	20%	12%	100%
Very likely	23%	10%	40%	36%	14%	100%
Somewhat likely	13%					
Not very likely	17%					
Not at all likely	38%					
Total	**100%**	**18%**	**31%**	**18%**	**5%**	**100%**

Weatherization Measures

The final targeted group was the weatherization measures installed through the LIEE program.[27] A total of 652 households were surveyed regarding their weatherization measures to determine if the measures were still installed. As shown in Table 48, the vast majority (97 percent) of the weatherization measures were still installed at the time of the survey. Of those households that reported the weatherization was no longer installed, all but one reported that the measure had broken or worn out. One household reported that they had installed a new door, and the vendor replaced all the weather stripping at that time.

Table 48. Is the Weatherization Still Installed?

Weatherization still installed?	Yes	No	Don’t Know
Still installed	97%	2%	1%

As with the other targeted measures, the survey asked the weatherization respondents about the likelihood of the respondent installing the weatherization measures in absence of the LIEE program. Table 49 shows that about a quarter (26 percent) of the respondents indicated that they were extremely or very likely to have installed the measures even if the LIEE program was not available. Of these, 55 percent indicated that they would likely have done so at the same time or within the year.

[27] Weatherization measures in the survey included weather stripping, caulking, and installation of door thresholds.

Table 49. Likelihood of Household Weatherizing Home Without the LIEE Program

Likelihood of household to weatherize home without LIEE Program		Estimated timing of weatherization without LIEE Program				
		At the Same Time	Within a Year	More than a Year	Don't Know/ Refused	Total
Extremely Likely	9%	31%	29%	25%	15%	100%
Very likely	17%	14%	39%	40%	8%	100%
Somewhat likely	22%					
Not very likely	23%					
Not at all likely	29%					
Total	**100%**	**20%**	**35%**	**35%**	**10%**	**100%**

Other Measures

The majority of the respondents had other measures installed through the program in addition to the targeted measures discussed above. A limited set of questions were asked regarding these measures to see if any additional information could be used in the billing regression models. Selected responses are also reported below.

The measures that fell into the “Other” category for the phone survey include the following:

- Air conditioning—included air conditioning assessment, tune up or repair, or air conditioning unit;
- Insulation—attic or wall insulation;
- Lighting—compact fluorescent light bulbs or some other type of low energy lighting;
- Aerator—low-flow showerhead or faucet aerator;
- Refrigerator—new refrigerator or a payment for a new refrigerator; and
- Water heater blanket.

The program participants received a mix of these measures, and the LIEE tracking data show that 1,945 measures were distributed to 1,183 surveyed households. We were able to confirm that the households received 91% of these measures. Table 50 shows the confirmation by individual measure types and the number of measures installed as contained in the program tracking data. The data show that some measure types—insulation and refrigerators—had very high confirmation rates (99 percent). The air conditioning and aerators had lower confirmation rates (80 percent and 86 percent, respectively) and the water heater blanket had the lowest confirmation rate at 43 percent.

Table 50. Confirmed Receipt of Measure

Did you have measure installed?	Number of Measures	Yes	No	Don't Know
Air conditioning	59	80%	14%	7%
Lighting	929	94%	4%	1%
Aerator	575	86%	10%	4%
Insulation	73	99%	1%	0%
Refrigerator	274	99%	1%	0%
Water heater blanket	35	43%	20%	37%
Total	**1,945**	**91%**	**6%**	**3%**

The survey questioned the households that confirmed they had received the measure if it was still installed. Table 51 shows that, across all these measures, 94 percent are still installed. All households that received insulation reported it is still installed, and almost all refrigerators are still installed. Air conditioning measures have a low portion of units still installed (87 percent) but the low rate is somewhat misleading as a higher portion of respondents did not know or refused to answer the question.

Table 51. Is the Measure Still Installed?

Measure still installed?	Yes	No	Don't Know/Refused
Air conditioning	87%	2%	11%
Lighting	94%	5%	1%
Aerator	92%	7%	0%
Insulation	100%	0%	0%
Refrigerator	99%	1%	0%
Water heater blanket	93%	0%	7%
Total	**94%**	**4%**	**1%**

The survey asked the respondents why the measure was no longer installed and answers tended to vary by measure:

- **Lighting**—40 households provided feedback and the majority (70 percent) stated the bulbs had burnt out and 10 percent had never installed them. Eighteen percent reported they did not like the light quality.
- **Aerators**—33 households provided feedback, with just over half (58 percent) reported the showerhead or aerator broke or did not work. About a quarter said they did not like the aerator and some specifically complained about the inadequate water volume. Another 15 percent had remodeled and the aerator had been removed.
- **Refrigerators**—three households provided feedback and all reported that the refrigerators did not work properly and therefore was removed.

The survey asked how likely the household would have been to install the energy efficiency measure in the absence of the LIEE program. Table 52 shows that about a third (35 percent) of the respondents stated that they were extremely or very likely to have installed the measures in their home without the LIEE program, which is consistent with the responses received for the targeted measures discussed above. Of these, 68 percent indicated that they would have installed the measures at the same time or within the year.

Table 52. Likelihood of Household to Install Other Measures without LIEE Program

Likelihood of household to weatherize home without LIEE Program		Estimated timing of installation without LIEE Program				
		At the Same Time	Within a Year	More than a Year	Don't Know/ Refused	Total
Extremely Likely	13%	34%	34%	26%	6%	100%
Very likely	22%	23%	44%	26%	7%	100%
Somewhat likely	23%					
Not very likely	18%					
Not at all likely	24%					
Total	**100%**	**27%**	**41%**	**26%**	**6%**	**100%**

Energy Education

The survey included some questions to understand the efficacy of the energy education component of the LIEE Program. It asked if the respondents had done anything to their home and if they do anything differently since participating in the LIEE Program. The first question focused on physical changes to the home and the second question focused on changes in habits.

Regarding physical changes to participants' homes, Table 53 shows that, across IOUs, only one-third of respondents had made some additional effort to alter their homes for improved energy efficiency. The table shows that respondents vary by IOU. SCG's energy education efforts regarding changes to the home appear to be more effective, as almost half of that utility's participants reported they had made changes to their home to save energy.

Table 53. Did Household Do Anything More to their Home to Try to Save Energy?

	PG&E	SCE	SCG	SDG&E	Total
Yes	27%	34%	47%	36%	32%
No	73%	66%	53%	64%	68%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

Most of the households that reported they had done something more to their home to save energy were able to provide explicit information about what they had done to their homes (86 percent). The changes to the homes included buying energy efficient appliances, installing insulation, installing weather stripping and caulking windows, purchasing additional CFLs, and planting shade trees in an effort to cool the house naturally.

Table 54. Changes Made to Homes

Type of Physical Change	Percent
Purchased EE appliance	27%
Installed insulation	19%
Weatherized home	51%
Installed EE lights	15%
Planted shade trees	13%

Note: Sum exceeds 100 percent because some households made multiple types of changes.

Regarding changes in habits, Table 55 shows that, across IOUs, a little over half of the respondents reported that they have tried to change their habits to try to save energy. SCG's customers were less likely to have changed their habits than customers of the three other IOUs. This contrasts with the results from the previous table, which showed SCG's customers were more likely to have made changes to their homes.

Table 55. Did Household Change its Habits to Try to Save Energy?

	PG&E	SCE	SCG	SDG&E	Total
Yes	60%	61%	38%	56%	57%
No	40%	39%	62%	44%	43%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

Note: Results weighted by strata.

Most of the households that reported they had changed their habits in order to save energy provided explicit information about what they do differently (80 percent). The responses included turning off lights, using the heater or air conditioner less, turning off appliances when not using them and unplugging appliances (see Table 56).

Table 56. Changes Made to Habits

Type of Habit Changed	Percent
Be mindful of energy consumption	21%
Turn off lights	52%
Unplug appliances when not in use	22%
Reduce use of heater/AC	9%
Close/open windows, doors	11%

Note: Sum exceeds 100 percent because some households made multiple types of changes.

6.2 On-site Survey Results

Two previous LIEE studies were unable to detect savings for repair or replacement of heating systems or installation of new evaporative coolers. Those studies posed two theories as to why savings from heating system measures and installation of evaporative coolers were not showing up in the models:

- The mild climates of California mean that many households do not use their systems as much as households in more extreme climates do. These moderate temperatures mean that larger energy savings normally expected in more severe climates may not be achieved in California. It is also hypothesized that fewer households used a consistent thermostat setting through the entire winter or summer period. The absence of a consistent thermostat setting means that heating degree days do not track well with heating use, and cooling degree days do not track well with cooling use in models.

- It was also assumed that some households that received heating or cooling repair or replacement had inoperable or poorly operating systems before treatment. The replacement or repair of these systems resulted in an increase in heating or cooling use in the post period.[28]

This study included an on-site survey that focused on collecting data that could help with models that include additional variables that were not available in earlier studies. The on-site survey collected detailed information about the home including square footage, equipment type, and operating characteristics that are only accurately collected by measurement of trained auditors. The survey also collected detailed information about the household including how the household used heating or cooling equipment before and after the program measures were installed. Our intent was to build this information into the on-site models.

Below, we provide evidence from the on-site survey results that confirm that treated households do not all behave as expected from engineering assumptions. Some households were found to not heat or cool when or as often as expected. Others were found to increase usage after the new equipment is installed; often because the systems were not previously used and were subsequently used more after repair or replacement.

Because the on-site survey was initiated to look at heating and cooling equipment measures, the evaluation team limited the survey to homes that received a new gas furnace or space heater, had repairs done to an existing gas furnace or space heater, or had received a new evaporative cooler. The sampling plan was designed to ensure that the warmer and colder climates of California were represented.

Table 57 compares the distribution of homes in the treated population and the actual samples for heating and cooling. The on-site sample for heating measures is similar to the population of homes receiving heating measures. The on-site sample has proportionally more homes in the more severe cooling climate than were found in the general population.

[28] It is worth noting that the earlier studies inability to identify energy savings from these measures may be due to the fact that the models are not properly specified or it may be because there was little or no savings achieved from these measures.

Table 57. Comparison of Population and Sample Distributions

	Population of Homes Receiving Heating Equipment or Repair		On-site Sample of Homes Receiving Heating Equipment or Repair	
	Number of Sites	**Percent**	**Number of Sites**	**Percent**
HDD<2100	11,116	77%	153	80%
HDD>2100	3,290	23%	37	20%
Total all Heating	**14,406**		**190**	
	Population of Homes Receiving Evaporative Coolers		**On-site Sample of Homes Receiving Evaporative Coolers**	
	Number of Sites	**Percent**	**Number of Sites**	**Percent**
CDD<2100	7,904	78%	117	61%
CDD>2100	2,228	22%	75	39%
Total all Cooling	**10,132**		**192**	

Characteristics of On-site Homes with Heating Measures

Heating Control

The on-site survey asked households to describe how they controlled the temperature of their homes. The results are presented below in Table 58. The table shows that most of the households in the milder climates did not rely on their thermostats. Even in the colder areas, one-third of the households did not use thermostats for control. There were several homes where the thermostat was set at a constant temperature, but those households reported that heat was only used when temperature dipped below a stated temperature. In these cases, household used an on/off switch to over-ride the thermostat setting; these households were placed in the manual control category.

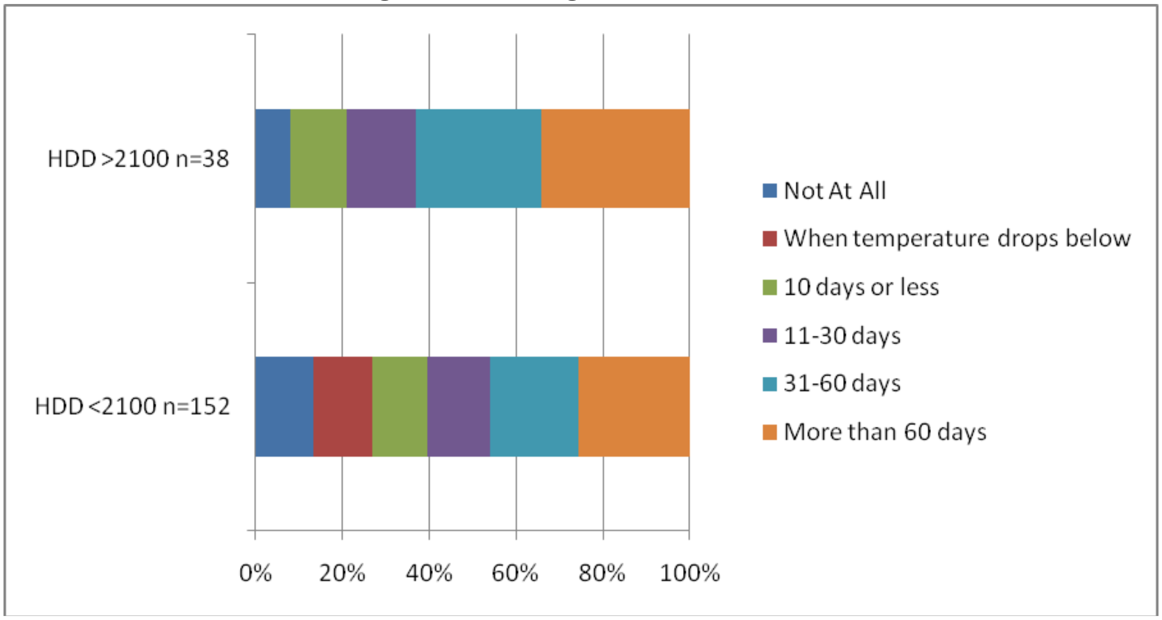
Table 58. Control Method of Heating

	Lower Degree Days <2100 HDD	Higher Degree Days> 2100 HDD
Set temperature and leave it	67	23
Setback using programmable thermostat	1	2
Manually adjust temperature as needed	84	13
Total	**152**	**38**

Duration of Heating Season

Figure 2 indicates that the period of heating is limited for most of the households. More than half of the homes use their heating systems 30 days or fewer each year. Few of the households use their heating systems on a continuous basis over the entire winter period. Only one household reported using their heating system more than 90 days in a season.

Figure 2. Heating Use over Season



Use of Gas Heater

Table 59 shows the reported primary heating source of the homes before and after the LIEE program intervention. The results indicate that only about five percent of the homes that were not using gas units before the intervention switched to a gas unit after receiving a repair or replacement. More surprising is the fact that many of the homes that received new gas units or gas repairs did not end up using them as a primary heating source. The study found that 23 percent (44 of 190) of the homes that received heater treatments were not using their gas heater as the primary heater in the period before the treatment. The majority of these homes (39) were in areas with mild climates. For many of these homes not using the heater, the treatment did not change their use pattern. Only 10 of the 44 homes that were not using their gas equipment as their primary heat before the program switched to a gas heater as primary after treatment. The other 34 households did not switch their use; either continuing to rely on an electric heater, stove, or not using any heating equipment.

Table 59. Primary Heating Source Before and After Program

	Before Program Intervention	After Program Intervention	Change
Gas Space Heater	49	55	6
Gas Furnace	97	101	4
Portable Electric Heater	22	15	-7
Stove	4	2	-2
None or Other	18	17	-1
Total	**190**	**190**	

The results in Table 59 above were further examined to see what type of treatment households that were not using gas heaters after intervention had received. Table 60 and Table 61 show the results broken down by whether unit was replaced or repaired. It appears that most households that received new heating systems did stop using electric space heaters or stoves as their primary heating source. However, most of the homes that received a heater repair that were using electric space heaters continued to rely on the electric heater as their primary heat even after the repair. In both cases, most homes that were relying on other heating sources or not using heat at all did not switch to using their gas-powered heating system, even when it was replaced or repaired.

Table 60. Primary Heating System for Homes Receiving New Heating Equipment

	Before Program Intervention	After Program Intervention	Change
Gas Space Heater	16	20	4
Gas Furnace	32	35	3
Portable Electric Heater	4	0	-4
Stove	3	1	-2
None or Other	4	3	-1
Total	**59**	**59**	

Table 61. Primary Heating System for Homes Receiving Heating Equipment Repairs

	Before Program Intervention	After Program Intervention	Change
Gas Space Heater	32	34	2
Gas Furnace	65	66	1
Portable Electric Heater	18	15	-3
Stove	1	1	0
None or Other	15	15	0
Total	**131**	**131**	

Use of Supplemental Heat

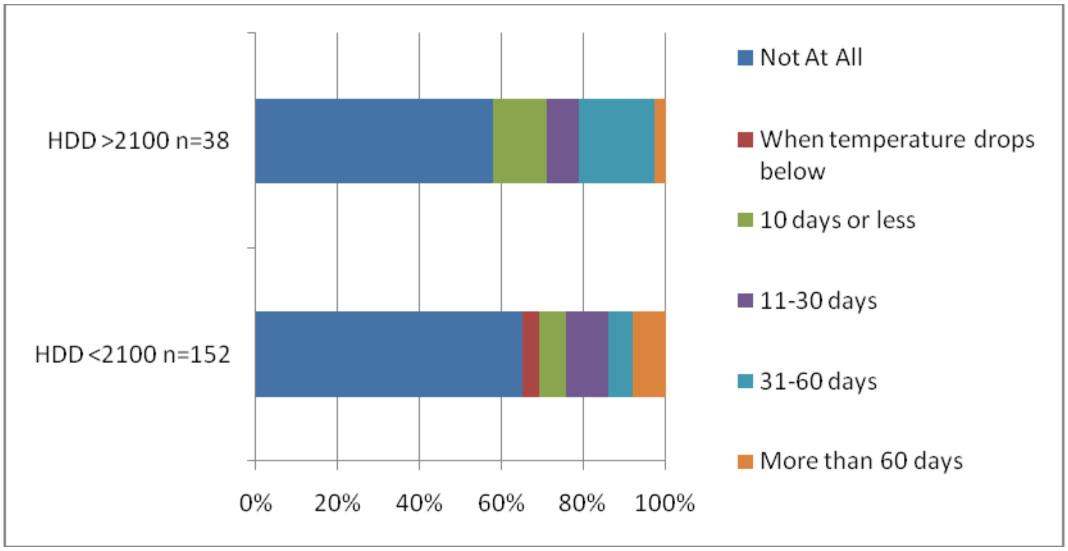
Another factor that contributes to the low savings estimates for heating measures is the use of supplementary heating sources by some of the program participants. These heating options include electric space heaters, kerosene heaters, wood stoves, and fireplaces. The use of any of these options reduces the need to use the primary heating source. It is worth noting that when asked to name their primary and secondary source of heating, some respondents listed a non-gas system as the primary unit and the gas-fired system as the supplementary source. As Table 62 indicates, more than a third (70 out of 190) of households use supplemental heat from a fuel source other than gas.

Table 62. Supplementary Heating Type

	HDD <2100	HDD >2100	Total
Cooking Stove	5	0	5
Portable Electric Space Heater	36	12	48
Gas Space Heater	1	0	1
Gas Furnace	10	2	12
None	88	19	107
Other	12	5	17
Total	**152**	**38**	**190**

While most of the households did not use supplemental heat or use it infrequently, there are some homes that are very dependent on its use. Figure 3 shows that 25 percent of the homes in the milder climate and 29 percent of the homes in the colder climate use supplemental heat at least 11 days a season.

Figure 3. Frequency of Supplemental Heating Use



Cooling Savings

Across the country, billing analysis studies have had a difficult time accurately accounting for cooling savings. The reasons for this are similar in nature to why the heating models for LIEE have been unsuccessful. Cooling loads are small relative to total load, and for many households who manually adjust the cooling device, cooling amounts are not consistently correlated to outside temperature. These problems are factors in our models.

Use of Cooling Equipment

The on-site survey asked households what their primary cooling equipment was three years ago. The survey then recorded any changes in this use over the three-year period. Table 63 shows the designated primary cooling systems at the beginning and end of the study period. There was a major shift from the use of compression-based air conditioning to evaporative cooling driven by the program.

Table 63. Change in Primary Cooling System after Treatment for Homes Receiving Evaporative Cooler

	Mild Climate <2100 CDD			Hot Climate >2100 CDD		
	Before	After	Change	Before	After	Change
Central Cooling	70	21	-49	47	37	-10
Room Air Conditioner(s)	15	4	-11	12	7	-5
Evaporative Cooler(s)	13	82	69	4	29	25
None	19	10	-9	12	2	-10
Total	117	117		75	75	

Table 64 shows that most households use both types of cooling systems.

Table 64. Use of Supplemental Cooling

	Mild Climate <2100 CDD	Hot Climate >2100 CDD
Uses Supplemental Cooling	86	52
Does Not Use Supplemental Cooling	31	23

Use of Cooling Thermostat

Most of the homes that received an evaporative cooler do not use a thermostat to set the amount of cooling that they use. Table 65 indicates that only half of the treated homes set a thermostat to control cooling. This makes it extremely difficult to build billing models that equate cooling use to weather conditions.

Table 65. Control Method for Cooling

	Mild Climate <2100 CDD	Hot Climate >2100 CDD
Set temperature and leave it	59	34
Setback using programmable thermostat	5	1
Manually adjust temperature as needed or not specified	53	40
Total	**117**	**79**

Duration of Cooling Season

Figure 4 shows the extent to which households use their primary cooling equipment. Even in the hotter areas, more than half of the households use their air conditioners less than 60 days per year.

Figure 4. Frequency of Primary Cooling

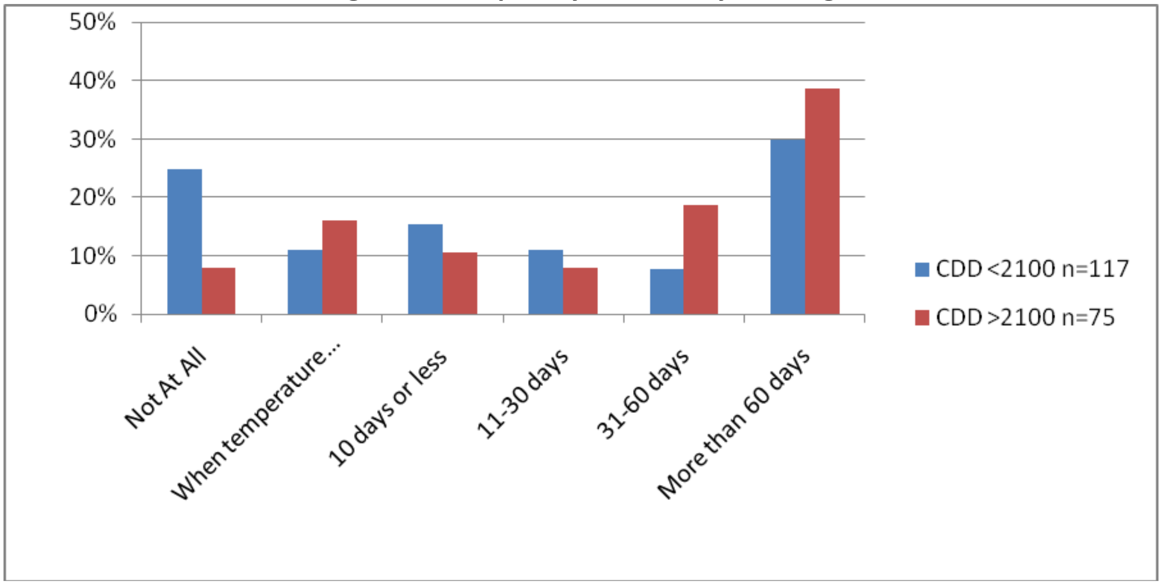
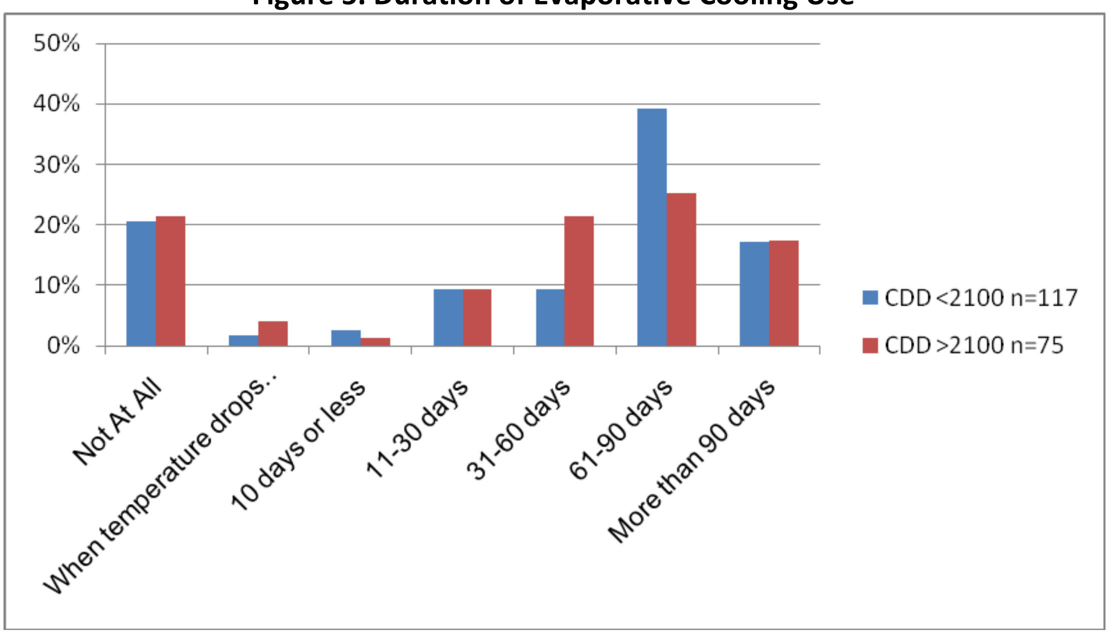


Figure 5 indicates that households rely heavily on their evaporative coolers. These units are allowed to run for longer periods than the primary cooling unit. It is worth noting that approximately 20% of the homes with evaporative coolers do not use them.

Figure 5. Duration of Evaporative Cooling Use



Another measure of the programs influence is shown in Table 66 where households report how their use of cooling has changed over time. Almost all of the households report using compression cooling less after the program. Over one-third report using the AC equipment a lot less than they used to.

Table 66. Program Effects on AC Use

	Mild Climate <2100 CDD	Hot Climate >2100 CDD	Total
Do not use AC at all anymore	27	11	38
Use AC a lot less than I used to	49	21	70
Use AC somewhat less than I used to	6	14	20
Use AC about the same as I used to	10	14	24
Use AC more than I used to	2	1	3
Don't know	2	0	2
Not applicable	21	14	35
Total	**117**	**75**	**192**

Education Effects

We asked a series of questions about the education sessions and whether they affected the household's behavior with respect to energy use. The general form of the question was "We are interested in hearing about any energy saving actions that you learned about from the education session given by the energy auditor who came to your home. You don't have to remember everything you did. Can you think of any actions, such as changes in the way you use equipment, or purchases you made that you learned from talking to the auditor and then started doing in your home?" Respondents were then asked if they were still practicing the measure or using the equipment and if so how frequently were they applying the measure.

We classified the results for those households who reported they are still using equipment purchased or practicing an energy saving measure more than rarely (see Table 67). It is worth noting that only 30% of the households report that the education session had a lasting impact on their behavior.

Table 67. Effects of Educational Sessions

	Number	Percent
Still doing at least one education action	118	30%
Turn off lights or equipment	37	9%
Buy CFLs	20	5%
Shade windows	6	2%
Turn up cooling setpoint	15	4%
Turn down heat	21	5%
Turn down hot water temperature	16	4%
Wash laundry with cold water	8	2%

CHAPTER 7: MODELING RESULTS

7.1 BILLING REGRESSION RESULTS

On-site and Phone Survey Regression Models

As discussed earlier in this report, neither the on-site nor phone survey regression models yielded results that could be used for the impact evaluation. A number of different model specifications were attempted for both the on-site and phone survey models, but none provided any improvement over the estimates obtained from the population model. Numerous different model specifications were attempted that included models with and without a non-participant control group (in the case of the phone survey regression), different use levels, and different combinations of interaction variables similar to the method followed with the population model. Despite attempting all reasonable specifications, problems with the on-site and phone survey models included insignificant coefficient estimates for key measures, estimates of zero savings, and coefficient estimates of the wrong expected sign.

The question arises as to which of the models using the on-sites sample, telephone sample, or full population supplies the best estimate of a measure savings. From our perspective the full population model provided the best estimate of measure saving as it alone includes a full set of participants and reflects overall savings. However, the smaller models were worth attempting as they have additional behavioral and house characteristic data that often help explain why some savings estimates are what they are. For example the on-site model indicated that previous use of heaters and changes in heater use were major factors in explaining savings. While we did not have the detailed information about previous use, we were able to restructure the full data model to define previous use categories that proved to be an effective means of including previous use as a factor in the final model.

Despite the fact that the on-sites and phone survey models did not result in improved impact estimates, they both yielded important information that helped inform this evaluation. Detailed results from the phone survey and on-sites are included in Chapter 6. The experience from these models will be useful in future evaluations should these types of billing regressions be considered again.

To maintain the focus of this report, only the results of the population model are discussed below (estimation results from the phone survey regression are included in Appendix C for reference).

Population Regression Model

To estimate the population models, the customer data were screened based on the following criteria:

- Participants with missing data in the climate zone or weather station fields were removed.
- All billing records that had days in their range before Jan 1, 2007 were removed.
- Billing data more than 400 days from the measure installation date were deleted.
- Participants with very low or very high consumption in any one month were removed. Low values were defined as less than 100 kWh for the electric model (no lower bound for gas given the seasonality of heating). High value thresholds were more than 1,500 kWh or 100 therms in any one month.
- Participants with less than 12 months of data prior to the measure installation or less than 12 months of data following the measure installation were removed.

Table 68 shows the number of observations dropped as a result of the screening process.[29] Although a significant number of observations were dropped due to monthly consumption being either too high or too low (based on the thresholds described above), the majority of dropped observations were due to other errors in the data.

Table 68: Results of Data Screening on Population Regression Dataset

	kWh Sample	Therm Sample
Raw unscreened data	110,544	118,420
Obs dropped for too high or too low monthly consumption	16,886	31,041
Obs dropped for other data errors	57,764	52,038
Final analysis dataset for regression model	35,894	35,341

Table 69 presents the results of the final population regression model for the electric. From the summary statistics, the model overall has explanatory power as evidenced by the significant F statistic and the R2 of 0.716. Most of the coefficient estimates are significantly different from zero, indicating that the model is benefiting from the specification that utilizes different use level interaction terms as well as interaction terms with the degree day variables.

The impact estimates derived from these model results are presented in the next chapter.

Table 69. Electric Population Regression Model Estimation Results

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Stat	Pr > F
Model	35,983	41,519,632,463	1,153,868	62.15	<1%
Error	887,248	16,471,197,821	18,564		
Corrected Total	923,231	57,990,830,284			

R-Square	Coefficient of Variation	Root MSE	Dependent Variable Mean
0.715969	30.4708	136.2511	447.1531

Variable[1]	Coefficient Estimate	Standard Error	t Stat	Pr > t
Refrig1	-15.5003	2.2579	-6.86	<1%
Refrig2	-39.5879	0.9655	-41.00	<1%
Refrig3	-68.9513	0.9206	-74.90	<1%
Refrig4	-111.7466	1.7128	-65.24	<1%
DHW1	13.9409	2.8832	4.84	<1%
DHW2	8.7575	1.7854	4.91	<1%

[29] In response to comments on a draft version of this report, the evaluation team re-estimated the population regression model with the high and low consumption screens relaxed to determine if the screening process itself was affecting the results. When the data screens were removed, the regression model performed significantly worse and resulted in lower impact estimates. Details on this alternative modeling exercise were written up in a separate memo that is included as *Appendix E* of this report.

DHW3	-2.6222	2.1856	-1.20	23%
DHW4	-43.7631	4.0346	-10.85	<1%
CFL	-7.8100	0.6512	-11.99	<1%
HardwiredFixtures	-7.9364	0.6208	-12.78	<1%
PoolPump	113.6029	25.8343	4.40	<1%
Evap1*CDD	0.0268	0.0188	1.43	15%
EvapSlope1*CDD	0.2026	0.0152	13.35	<1%
Evap2*CDD	-0.1351	0.0074	-18.19	<1%
EvapSlope2*CDD	0.6219	0.0064	96.70	<1%
Evap3*CDD	-0.5956	0.0118	-50.56	<1%
EvapSlope3*CDD	1.2425	0.0099	125.79	<1%
AC1*CDD	0.0284	0.0252	1.13	26%
ACSlope1*CDD	0.3558	0.0218	16.32	<1%
AC2*CDD	-0.0254	0.0224	-1.13	26%
ACSlope2*CDD	0.7164	0.0195	36.71	<1%
AC3*CDD	-0.1320	0.0461	-2.86	0%
ACSlope3*CDD	1.1025	0.0392	28.12	<1%
Insulation1*HDD	-0.0200	0.0829	-0.24	81%
InsulationSlope1*HDD	0.3092	0.0748	4.13	<1%
Insulation2*HDD	-0.0222	0.0603	-0.37	71%
InsulationSlope2*HDD	0.4108	0.0557	7.38	<1%
Insulation3*HDD	0.0115	0.0482	0.24	81%
InsulationSlope3*HDD	0.6778	0.0410	16.51	<1%
Insulation4*HDD	0.1978	0.0951	2.08	4%
InsulationSlope4*HDD	0.9537	0.0817	11.68	<1%
Insulation1*CDD	-0.0462	0.1349	-0.34	73%
InsulationSlope1*CDD	0.2268	0.1211	1.87	6%
Insulation2*CDD	-0.0821	0.0424	-1.94	5%
InsulationSlope2*CDD	0.7643	0.0354	21.58	<1%
Insulation3*CDD	-0.1483	0.0625	-2.37	2%
InsulationSlope3*CDD	1.6018	0.0528	30.35	<1%
Weather*HDD	0.0452	0.0050	8.99	<1%
WeatherSlope*HDD	0.6401	0.0044	145.23	<1%
Weather*CDD	-0.0776	0.0077	-10.11	<1%
WeatherSlope*CDD	0.7852	0.0066	119.00	<1%
NonWorkingAC_AC*CDD	0.3614	0.0086	41.98	<1%
NonWorkingAC_Evap*CDD	0.3614	0.0055	65.66	<1%
NoHeatSlope1*HDD	0.2087	0.0027	78.76	<1%
NoHeatSlope2*HDD	0.3598	0.0019	185.24	<1%
NoHeatSlope3*HDD	0.6076	0.0023	269.04	<1%
NoHeatSlope4*HDD	1.0361	0.0042	248.71	<1%
NoCoolSlope1*HDD	0.5006	0.0024	209.57	<1%
NoCoolSlope2*HDD	0.7674	0.0018	416.89	<1%
NoCoolSlope3*HDD	1.1261	0.0030	373.74	<1%
NoCoolSlope4*HDD	1.4888	0.0176	84.35	<1%

1. The monthly trend variable estimates were omitted from this table.

The summary statistics and model output for the final gas population model are shown in Table 70. As with the electric model, the gas population demonstrates significant explanatory power with an R2 of

0.78 and a significant F statistic. The coefficient estimates are generally also very significant, which again helps justify the model specification that utilizes interaction terms by use level and by degree day.

Table 70. Gas Population Regression Model Estimation Results

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Stat	Pr > F
Model	40,969	244,504,325	5,968.0	84.58	<1%
Error	977,935	69,002,665	70.6		
Corrected Total	1,020,000	313,506,990			

R-Square	Coefficient of Variation	Root MSE	Dependent Variable Mean
0.779901	32.0673	8.39997	26.1948

Variable	Coefficient Estimate	Standard Error	t Stat	Pr > t
BillingYear2	0.0321	0.0242	1.32	19%
BillingYear 3	1.2565	0.0372	33.80	<1%
BillingYear 4	4.1379	0.2754	15.02	<1%
DHW1	0.0530	0.0644	0.82	41%
DHW2	0.2065	0.0369	5.60	<1%
DHW3	-0.9523	0.0378	-25.22	<1%
DHW4	-3.2211	0.0654	-49.27	<1%
WaterHeater	0.1469	0.0897	1.64	10%
Insulation1*HDD	0.0047	0.0019	2.48	1%
InsulationSlope1*HDD	0.0109	0.0016	6.73	<1%
Insulation2*HDD	0.0001	0.0006	0.24	81%
InsulationSlope2*HDD	0.0454	0.0005	97.48	<1%
Insulation3*HDD	-0.0098	0.0005	-18.53	<1%
InsulationSlope3*HDD	0.0884	0.0004	206.87	<1%
Insulation4*HDD	-0.0101	0.0012	-8.19	<1%
InsulationSlope4*HDD	0.1189	0.0009	127.91	<1%
Weather1*HDD	0.0029	0.0004	7.96	<1%
WeatherSlope1*HDD	0.0109	0.0002	45.86	<1%
Weather2*HDD	-0.0002	0.0002	-1.23	22%
WeatherSlope2*HDD	0.0476	0.0001	393.65	<1%
Weather3*HDD	-0.0058	0.0002	-30.88	<1%
WeatherSlope3*HDD	0.0879	0.0001	612.27	<1%
Weather4*HDD	-0.0076	0.0005	-16.78	<1%
WeatherSlope4*HDD	0.1218	0.0004	336.65	<1%
HeatingSystem1*HDD	0.0374	0.0017	21.49	<1%
HeatingSystemSlope1*HDD	0.0098	0.0015	6.68	<1%
HeatingSystem2*HDD	0.0212	0.0005	42.44	<1%
HeatingSystemSlope2*HDD	0.0407	0.0004	99.53	<1%
HeatingSystem3*HDD	0.0152	0.0004	33.77	<1%
HeatingSystemSlope3*HDD	0.0670	0.0004	181.11	<1%
HeatingSystem4*HDD	0.0057	0.0008	6.80	<1%

HeatingSystemSlope4*HDD	0.0771	0.0007	109.50	<1%
Ducts1*HDD	0.0137	0.0015	9.01	<1%
DuctsSlope1*HDD	0.0099	0.0014	7.24	<1%
Ducts2*HDD	0.0020	0.0004	5.16	<1%
DuctsSlope2*HDD	0.0582	0.0003	182.21	<1%
Ducts3*HDD	-0.0007	0.0004	-1.91	6%
DuctsSlope3*HDD	0.0998	0.0003	330.46	<1%
Ducts4*HDD	0.0018	0.0011	1.69	9%
DuctsSlope4*HDD	0.1414	0.0009	165.27	<1%
Pre_NoHeat*HDD	-0.0018	0.0002	-7.39	<1%
NoHeat*HDD	0.0609	0.0002	286.10	<1%

7.2 Engineering Review

A few measures were not covered by population regression models, either because they were new measures in 2009 or else had too low of savings (or too few observations) to have a noticeable effect in the population model. In these instances, we used the *ex ante* impact estimates to calculate savings after the *ex ante* estimates were reviewed by staff from Michaels Engineering.

Table 71 shows the measures where the *ex ante* values are used. As shown, the number of measures had generally low participation (with the exception of occupancy sensors and night lights) and comprised a small fraction of overall savings for PY2009. Given the small amount of savings involved, the engineering analysis conducted was minimal and involving a desk review of the savings values and source documentation. This allowed us to focus more evaluation resources on the regression analysis to make sure that all reasonable modeling options were explored.

Table 71. Measures Where *Ex Ante* Savings Values Are Used

Measure	Utility	# installations	kWh Savings	Therm Savings
Microwave	SDG&E	265	185,076	--
Microwave	PG&E	315	325	4,745
High Efficiency Clothes Washer	PG&E	27	21,272	--
Torchiere	PG&E	7786	1,565,875	--
Torchiere	SCE	1734	329,284	--
Torchiere	SDG&E	4725	1,296,126	--
Thermostatic Shower Valve	SDG&E	2,472	74,613	45,669
FAU Standing Pilot Light Conversion	SDG&E	183	--	7,728
Heat Pump Replacement	SCE	65	49,588	--
Occupancy Sensor	PG&E	15,853	841,970	--
LED Night Light	SDG&E	10,075	293,324	--
Central AC Tune-up	SDG&E	40	8,854	--
Central AC Tune-up	PG&E	22	1,331	--
Central AC Tune-up	SCE	16	15,272	--
Furnace Clean and Tune	SCG	2110	--	5,864

CHAPTER 8: IMPACT RESULTS

8.1 SUMMARY OF IMPACTS

Total program energy savings by utility are summarized in Table 72. In aggregate, the LIEE PY2009 program activity reached 240,329 homes, savings 57.5 GWh, 12.7 MW and 1.6 million therms.

Table 72. PY2009 Total Program Savings

	# of Participants	Annual MWh	Coincident Peak (KW)	Annual Therms
PG&E	81,516	32,788	5,547	707,809
SCE	71,896	17,773	6,453	1
SDG&E	20,835	6,320	679	168,847
SCG	66,082	616	58	710,979
Totals	240,329	57,497	12,737	1,587,637

Table 73 provides a summary of those impacts that were estimated from the population regression model. For those measures where the regression model estimated a negative savings impact (i.e., the model predicted an *increase* in energy use rather than savings for that measure), the savings number was set to zero. Table 73 also shows how many observations were available in the regression dataset to estimate impacts for each measure. In general, there were sufficient sample points to allow for confidence in the impact estimates. In a few cases such as pool pumps and insulation, the regression sample was smaller and therefore results in a lower level of confidence in the impact estimates.

For all other measures not shown in Table 73, the *ex ante* savings values were used to calculate total 2009 savings. The measures where the *ex ante* savings values were used are typically smaller impact measures and/or measures with low participation levels, where savings are therefore difficult to estimate with the population regression model.

Table 73. Source of Final Impact Estimates

Measure	Number of Participants (Regression)	Model Estimated Impact (Positive = Savings)	Final Impact Source
Refrigerator	9,086	Positive	Regression estimate
DHW Conservation	2,253	Negative	Set to zero
CFL	32,077	Positive	Regression estimate
HWD Light	11,951	Positive	Regression estimate
Pool Pump	7	Negative	Set to zero
Evaporative Cooler	1,191	Positive	Regression estimate
AC	112	Positive	Regression estimate
Insulation/Heating	44	Negative	Set to zero
Insulation/Cooling	58	Positive	Regression estimate
Weatherization/Heating	1,213	Negative	Set to zero
Weatherization/Cooling	803	Positive	Regression estimate

Table 74 shows the annual estimated household savings for the 2000, 2001, 2002, 2005 and 2009 evaluations, along with the annual energy consumption for the group of 2009 program participants used in the regression models, during the pre-installation period.

Table 74. Comparison of Household Savings, PY2000 to PY2009

	Average Annual Pre-Installation Energy Consumption[30]	PY2009 Evaluation	PY2005 Evaluation	PY2002 Evaluation	PY2001 Evaluation	PY2000 Evaluation
Electric Savings (kWh)						
Combined Utilities[31]	5,752	330	423	366	213	175
PG&E	5,933	402	433	399	236	240
SCE	5,819	247	435	286	203	153
SDG&E	4,580	303	342	370	215	89
Gas Savings (Therms)						
Combined Utilities	318	9	18	8	18	24
PG&E	331	9	19	9	18	28
SDG&E	260	8	14	4	13	13
SCG	317	11	17	17	20	26

Electric savings increased steadily from 175 kWh per year in PY2000 to 423 kWh in PY2005 before decrease to 330 kWh in the PY2009. The current savings estimate represents a decrease of approximately 7% in electric consumption on average. The PY2009 electric savings are about 22% lower than they were in PY2005, with the largest decreasing occurring in SCE's service territory.

Table 75 present the electric savings by major measure group. This analysis shows that refrigerators and lighting measures combined account for almost 82% of the total program energy savings, and 53% of the estimated coincident peak reduction. Cooling, DHW, and air sealing/envelope measures make up the majority of the remaining savings.

Table 75. Electric Savings by Measure Group

End Use	Savings per Home (kWh)	Energy Savings (MWh)	% of Total	Coincident Peak Demand Savings (KW)	% of Total
Refrigerators	697	24,628	43%	4,187	34%
Lighting	346	22,226	39%	2,376	19%
HVAC (Cooling)	351	4,895	9%	5,747	46%
Hot Water Conservation	24	309	1%	52	0%
Air Sealing/Envelope	63	4,597	8%	0	0%
Totals		56,656		12,361	

[30] This column reflects the average annualized pre-installation kWh consumption for 2008 participants who were included in the population regression analysis dataset.

[31] Combined utility average consumption was calculated from the data set used for the regression analyses. Household savings was derived by summing the savings separately for each of the four utilities and dividing by the total number of participants.

The gas savings are more variable from one year to the next. As shown in Table 74, the average household savings for the statewide program are 9 therms per year, or 3% of gas consumption on average. While this represents a household savings decrease of almost 50 percent from PY2005, as a share of consumption it is similar to PY2005, when therm savings were 4 percent of average household consumption.

Table 76 shows the gas savings by measure group. Hot water conservation and air sealing/envelope measures have low household savings and high penetration, and in combination account for almost 95% of the total program savings. Although the current evaluation did not find savings for the hot water and heating replace/repair measures, the level of participation in these areas comprised a smaller share of total participation at approximately 12 percent of households receiving gas measures. As discussed elsewhere in this report, the lack of heating savings is consistent with information obtained from participants through the phone and on-site surveys, which indicate low levels of heating use in general and a significant number of households increasing heater use after participating in the LIEE program.

Table 76. Gas Savings by Measure Group

	# of Households	Savings per Home (Therms)	Total Program Savings (Therms)	% of Program Savings
Hot Water Conservation	133,397	7	956,274	61%
Air Sealing/Envelope	131,028	4	529,454	34%
Attic Insulation	8,010	10	83,572	5%
Hot Water Repair/Replace	4,704	0	0	0%
Heating System Repair/Replace	32,984	0	0	0%

8.2 Impact Results Discussion

Comments on a draft version of this report have focused on a desire to explain why the results in the current evaluation are different from the last impact evaluation in 2005. One must not conclude from these differences across time that one set of estimates is ‘correct’ or ‘more accurate’ than the other; the estimates may be equally accurate but reflecting different market conditions inherent in two different evaluation periods (e.g., changing weather conditions and/or the current recession versus the more robust economic conditions in 2005, for example).

Table 77 and Table 78 compare the results of the current evaluation with the 2005 impact evaluation and earlier evaluations. While the current estimates are different from 2005, they are generally within the historical range from previous evaluations. As this comparison indicates, there is significant variation across data sources and evaluation years in the impact estimates. While some of this difference may be attributable to differences in impact estimation methods, there are also differences in underlying program and market conditions that contribute to the variation, including changes in the economy, weather, program implementation, customer attitudes toward energy efficiency, and the cumulative effect of efficiency programs in California over time.

Table 77. Comparison of Electric Impacts with Previous Evaluations

End Use	2009 Evaluation (kWh)	2005 Evaluation (kWh)	Previous LIEE Evaluations (kWh)
CFL	16	11	22-43
Refrigerator	711	755	645-795
Attic Insulation (Cooling)	103	257	44-208
Attic Insulation (Heating)	0	70	35-288
Evaporative Cooler	504	245	98-571

Table 78. Comparison of Gas Impacts with Previous Evaluations

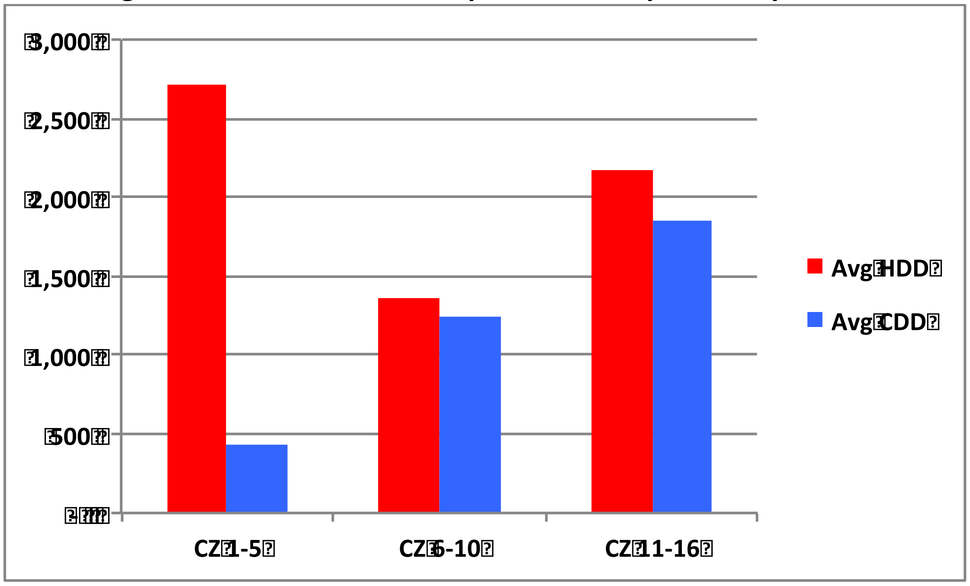
End Use	2009 Evaluation (therms)	2005 Evaluation (therms)	Previous LIEE Evaluations (therms)
Hot Water Conservation	7.5	13.5	10-20
Air Sealing/Envelope	4.6	6.1	3-11
Attic Insulation	10.1	47.2	10-59
Hot Water Repair/Replace	0	12.1	9-19
Heating System Repair/Replace	0	2.4	0-147

In an attempt to shed some light on the differences between the current impact evaluation and the 2005 impact evaluation, we examined in more detail the shifts in participation by climate zone for weather-dependent gas measures. We limited our focus on those measures that had low (or zero) impacts in the current evaluation relative to the 2005 evaluation.

A possible explanation for the lower impact estimates for weather-dependent measures is that participation has shifted toward milder climate zones (or that weather conditions were milder in the 2009 evaluation relative to the 2005 analysis). For weather-dependent measures such as furnace replacement/repair and insulation, for example, a relative increase in participation in milder climates would reduce the average impact as heating loads would be reduced.

Figure 6 shows the HDD and CDD for the 16 climate zones used in the 2009 impact evaluation, with zones aggregated into three groups; climate zone 1-5 (group 1), climate 6-10 (group 2), and climate zones 11-16 (group 3). As can clearly be seen from Figure 6, the middle climate zone group (climate zones 6-10) has milder temperatures for heating. Consequently, we would expect lower impact estimates for weather-dependent heating measures installed in these zones relative to the other areas (all else equal).

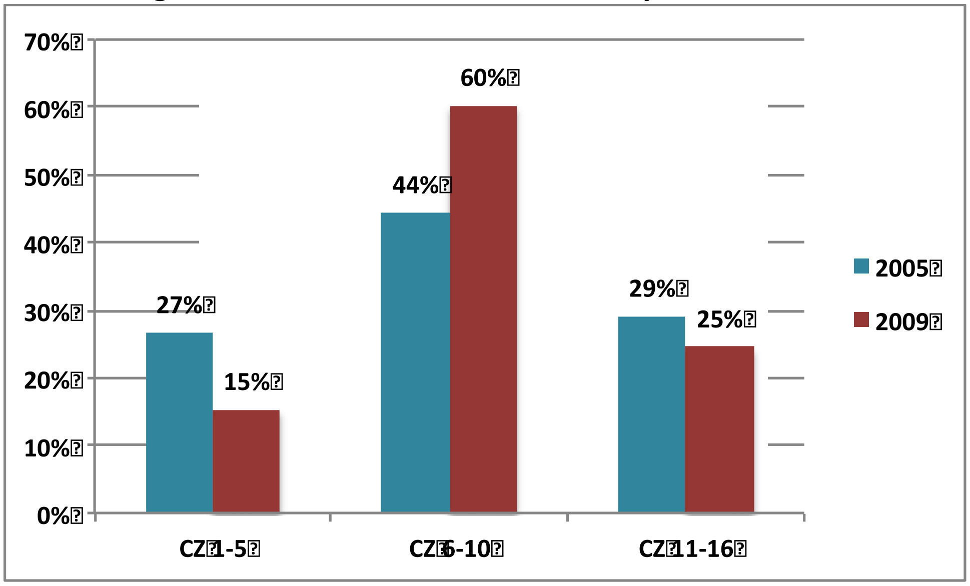
Figure 6. Climate Zone Groups for LIEE Impact Comparison



The next step is to compare the distribution of installations in these climate zone groups for those weather-dependent measures with very low or zero estimated impact in the current evaluation. Figure 7 shows the comparison of installations for the weatherization measure group.[32] There is a pronounced shift of the installation of these measures from the more extreme climate zones 1-5 to the milder areas of climate zone 6-10. In the 2009 impact evaluation, the installation of weatherization measures in the milder zones increased from 44 to 60 relative to the 2005 evaluation. This was primarily due to fewer installations in the more extreme climate zones 1-5, which decreased from 27 percent in 2005 to 15 percent in 2009.

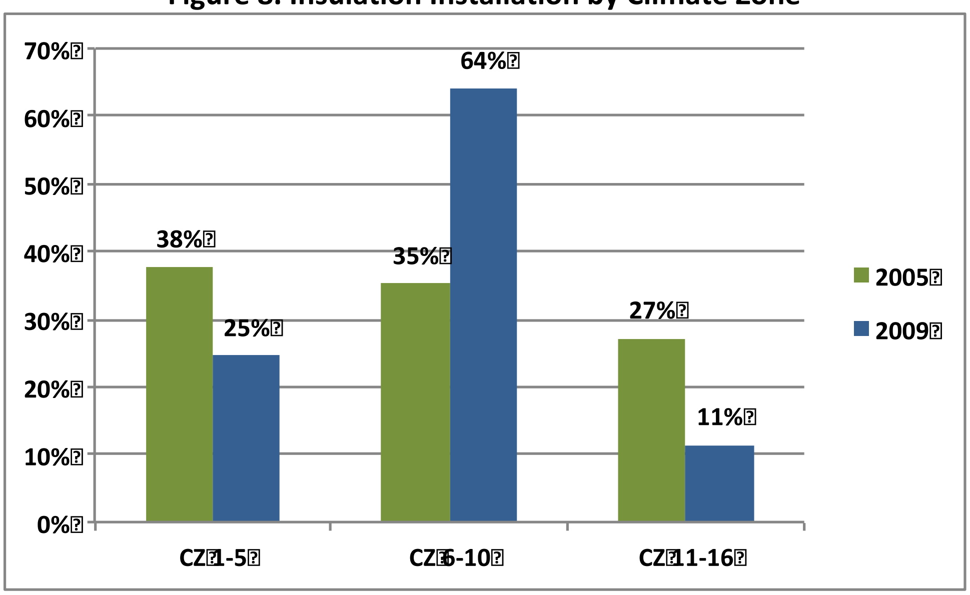
[32] Note that in the climate comparison charts, 2009 refers to the impact evaluation year. The data used to create these charts are actually from 2008 participants, to be consistent with the other data used to estimate the regression model.

Figure 7. Weatherization Installation by Climate Zone



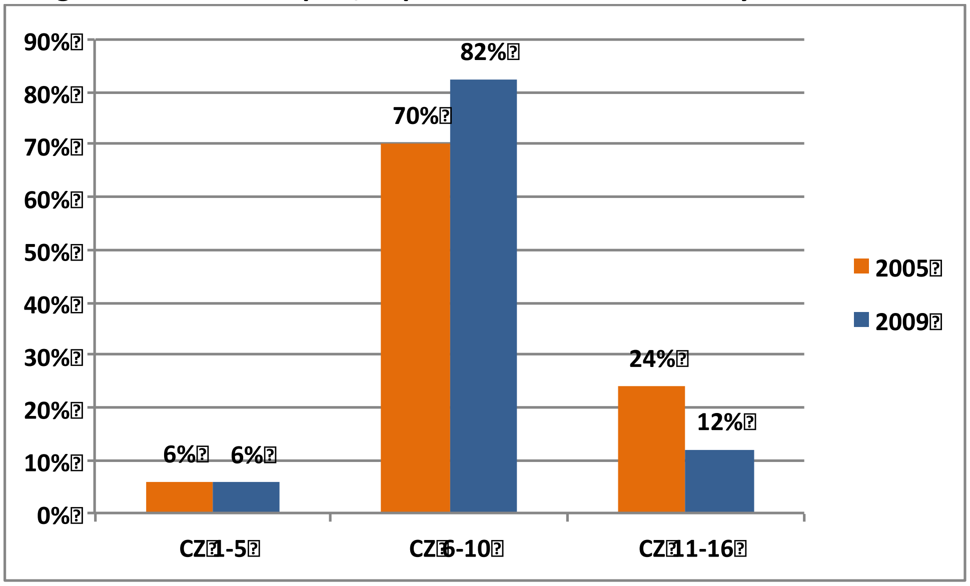
A similar shift to milder climate zones is also apparent for the gas insulation measures, as shown in Figure 8. In this case, the shift to the milder climates zones is even more pronounced. In the colder climate zones 1-5, weatherization installations decreased from 38 to 25 from 2005 to 2009. This corresponded to an increase in installations in the milder climates zones 6-10, which saw its share almost double from 35 percent in 2005 to 64 percent in 2009.

Figure 8. Insulation Installation by Climate Zone



Finally, the comparison of furnace repair and replacement by climate zone is shown in Figure 9. Here the shift to milder climates zones is less pronounced, with an increase from 70 to 82 percent in the share of installations in the milder climate zones 6-10. As discussed below, however, there are additional shifts in climate zones among customer user categories that provide information on the lower impact estimates for the furnace repair/replacement measure group.

Figure 9. Furnace Repair/Replacement Installations by Climate Zone



The preceding figures suggest that at least part of the decrease in impact estimates relative to 2005 can be explained by a shift in participation to milder climate zones for the weather-dependent gas measures.

Some additional analysis was done to see how changes in weather across different categories of energy usage groups might be affecting the impact estimates. In the population billing regression for both 2005 and 2009, the model divides participants into four use levels (based on consumption) and consumption was incorporated separately as an interactive term so that impact estimates are in part a function of kWh or therms consumed. As a result of this specification, we would generally expect that impacts would increase with overall usage for weather-dependent measures (other things equal). This was generally the case in 2005, but as demonstrated in the following tables, a significant drop in HDD from 2005 for the highest usage groups is contributing to the lower overall impact estimates for these measures.

Table 79 shows this comparison for the furnace repair/replacement measure group. Note that here and throughout the report, savings are indicated with a *positive* number. In cases, where a negative impact is estimated (i.e., the model estimates an *increase* in usage for that measure), the impact value is set to zero.

For the higher usage groups (Use Level 3 and 4) that had the furnace repair/replacement measure, the average number of heating degree days dropped substantially for both the higher use groups (highlighted in yellow). Since the impact estimates are calculated using heating degree days, the decrease in HDD led to a corresponding drop in the impact estimates for these two groups. Since the impact estimate is negative in 2009 for all four use levels, the final impact estimate was set to zero.[33]

[33] As discussed in the survey section of this report, both the phone survey and on-site respondents indicated that a significant number of the furnace repairs and replacements occurred on furnaces that were not working prior to the program intervention. A significant number of respondents also indicated that they use their heating system more since participating in

Table 79. Furnace Repair/Replace Impact Comparison by Usage and Weather

Use Level	Average Annual HDD		% Change	Savings (therms/yr)	
	2005	2009		2005	2009
1	1,775	1,738	-2%	-13.8	-65.0
2	1,827	1,674	-8%	-15.9	-35.5
3	1,895	1,437	-24%	11.0	-21.8
4	2,014	1,249	-38%	38.2	-7.2

A similar result was found for the insulation measures when changes in HDD are compared for the individual use level groups. The comparison of therm impacts and HDD are shown in Table 80 for both the 2005 and 2009 evaluations. For both the higher use categories, HDD decreased significantly between the two analysis periods. This resulted in a significant decrease in the impact estimates for insulation in 2009, as highlighted below in the last two rows of Table 80.

Table 80. Insulation Impact Comparison by Usage and Weather

Use Level	Average Annual HDD		% Change	Savings (therms/yr)	
	2005	2009		2005	2009
1	1,688	1,881	11%	-1.3	-8.8
2	1,925	1,923	0%	8.9	-0.3
3	2,120	1,646	-22%	48.1	16.1
4	2,231	1,260	-44%	90.8	12.8

The preceding analysis suggests that much of the change in impact estimates for weather-dependent measures can likely be attributed to a shift in participation to milder climates and/or milder weather conditions relative to the 2005 impact analysis.

The remainder of this chapter presents detailed tables by utility and fuel type for the measure-level impacts. Additional tables providing detail on impacts by climate zone and house type are included in Appendix D.

8.3 Detailed Gas Savings

The estimated gas savings for PG&E, SCE, SCG, and SDG&E are shown in the following tables. The tables show estimates for four categories of measures: domestic hot water, enclosure, HVAC systems, and maintenance. For each measure and housing type, the tables show the number of participating households and the number of installed items. Finally, the tables show the per-unit savings, the per-household savings, and the total program savings.

the program. Give this information, it is not surprising that the billing regression model returned a negative impact estimate as many of these customers are actually increasing their furnace use after participating in the program.

Table 81. PG&E Gas Savings

Measure Category	Measure Name	House Type	Number of House-holds	Number of Items Installed	Savings per Unit (therm)	Savings per Household (therm)	Total Program Savings (therm)
Appliances	Microwave	All	313	115	41.26	15.16	4,745
Domestic Hot Water	Faucet Aerator	Single Family	25,387	48,664	2.06	3.96	100,481
		Multifamily	14,167	24,141	0.24	0.41	5,827
		Mobile Homes	1,999	3,730	1.80	3.36	6,727
	Low Flow Shower Head	Single Family	23,078	31,551	4.54	6.21	143,201
		Multifamily	12,184	13,172	0.63	0.68	8,304
		Mobile Homes	1,410	1,680	5.71	6.80	9,586
	Water Heater Blanket	Single Family	9,922	9,749	6.50	6.39	63,391
		Multifamily	3,032	3,003	1.22	1.21	3,676
		Mobile Homes	514	484	8.77	8.26	4,244
	Water Heater Pipe Insulation	Single Family	227	361	14.23	22.63	5,136
		Multifamily	68	194	1.54	4.38	298
		Mobile Homes	37	115	2.99	9.29	344
	Water Heater Repair / Replacement	Single Family	2,224	2,227	0.00	0.00	0
		Multifamily	35	35	0.00	0.00	0
		Mobile Homes	62	159	0.00	0.00	0
Enclosure	Air Sealing / Envelope	Single Family	35,737	213,528	18.92	71.43	255,998
		Multifamily	17,787	79,832	1.69	5.30	9,427
		Mobile Homes	3,084	15,148	22.63	79.21	25,432
	Attic Insulation	Single Family	4,325	4,941,650	0.01	13.39	57,906
		Multifamily	612	499,378	0.01	5.04	3,086
HVAC	Duct Testing and Sealing	All	9,224	8,910	0.00	0.00	0
	Furnace Repair / Replacement	All	2,890	2,898	0.00	0.00	0

Table 82. SCE Gas Savings

Measure Category	Measure Name	House Type	Number of House-holds	Number of Items Installed	Savings per Unit (therm)	Savings per Household (therm)	Total Program Savings (therm)
Enclosure	Air Sealing / Envelope	Multifamily	4	26	0.05	0.34	1

Table 83. SCG Gas Savings

Measure Category	Measure Name	House Type	Number of House-holds	Number of Items Installed	Savings per Unit (therm)	Savings per Household (therm)	Total Program Savings (therm)
Domestic Hot Water	Faucet Aerator	Single Family	52,615	109,756	0.89	1.85	97,246
		Multifamily	14,937	27,291	0.11	0.19	2,868
		Mobile Homes	6,509	14,596	0.35	0.79	5,133
	Low Flow Shower Head	Single Family	55,603	72,794	4.27	5.60	311,119
		Multifamily	14,432	15,665	0.59	0.64	9,174
		Mobile Homes	7,293	9,828	1.67	2.25	16,421
	Water Heater Blanket	Single Family	5,307	5,353	5.34	5.39	28,580
		Multifamily	632	650	1.30	1.33	843
		Mobile Homes	885	891	1.69	1.70	1,508
	Water Heater Pipe Insulation	Single Family	2,972	3,005	3.87	3.92	11,640
		Multifamily	527	533	0.64	0.65	343
		Mobile Homes	439	447	1.37	1.40	614
	Water Heater Repair / Replacement	Single Family	2,210	2,560	0.00	0.00	0
		Multifamily	3	3	0.00	0.00	0
		Mobile Homes	132	139	0.00	0.00	0
Enclosure	Air Sealing / Envelope	Single Family	44,914	321,900	5.81	52.01	185,937
		Multifamily	11,652	51,582	0.75	3.58	3,343
		Mobile Homes	2,712	80,467	3.47	53.59	12,521
	Attic Insulation	Single Family	2,429	2,130,755	0.01	7.23	17,568
		Multifamily	97	68,849	0.00	2.65	257
HVAC	Duct Testing and Sealing	All	14,648	14,981	0.00	0.00	0
	Furnace Repair / Replacement	All	28,309	28,380	0.00	0.00	0

Maintenance	Furnace Clean and Tune	Single Family	2,079	2,151	8.60	8.38	5,708
		Mobile Homes	31	31	9.00	9.00	156

Table 84. SDG&E Gas Savings

Measure Category	Measure Name	House Type	Number of House-holds	Number of Items Installed	Savings per Unit (therm)	Savings per Household (therm)	Total Program Savings (therm)
Domestic Hot Water	Faucet Aerator	Single Family	7,089	15,501	1.60	3.51	24,848
		Multifamily	8,222	17,373	0.19	0.40	3,261
		Mobile Homes	156	419	1.30	3.49	544
	Low Flow Shower Head	Single Family	7,121	9,804	3.94	5.42	38,612
		Multifamily	7,752	9,995	0.51	0.65	5,068
		Mobile Homes	165	258	3.28	5.13	846
	Thermostatic Shower Valve	All	2,472	3,545	13.60	19.50	48,212
	Water Heater Blanket	Single Family	928	932	3.51	3.52	3,267
		Multifamily	148	150	2.86	2.90	429
		Mobile Homes	31	31	2.31	2.31	72
	Water Heater Pipe Insulation	Single Family	336	1,258	0.37	1.38	464
		Multifamily	71	200	0.30	0.86	61
		Mobile Homes	38	152	0.07	0.27	10
	Water Heater Repair / Replacement	Single Family	32	32	0.00	0.00	0
		Mobile Homes	6	6	0.00	0.00	0
Enclosure	Air Sealing / Envelope	Single Family	6,797	83,280	2.39	26.89	32,804
		Multifamily	8,172	47,106	0.19	1.16	3,018
		Mobile Homes	169	2,183	3.36	18.64	972
	Attic Insulation	Single Family	539	582,414	0.01	8.77	4,728
		Multifamily	8	8,674	0.00	3.32	27
HVAC	Duct Testing and Sealing	All	494	497	0.00	0.00	0
	FAU Standing Pilot Light Conversion	All	183	184	42.00	42.23	7,728
	Furnace Repair / Replacement	All	1,785	1,802	0.00	0.00	0
Maintenance	Furnace Clean and Tune	All	9,245	9,519	0.00	0.00	0

8.4 DETAILED ELECTRIC SAVINGS

The estimated electric savings for PG&E, SCE, SCG, and SDG&E are shown in the following tables. The tables show estimates for six categories of measures: appliances, domestic hot water, enclosure, HVAC systems, lighting, and maintenance. For each measure and housing type, the tables show the number of participating households and the number of installed items. The tables also show the per-unit savings, the per-household savings, and the total program savings. Finally, the tables show the per-unit peak savings, the household peak savings, and the total coincident peak.

Table 85. PG&E Electric Savings

Measure Category	Measure Name	House Type	# of Households	# of Units Installed	Savings per Unit (kWh)	Savings per Household (kWh)	Total Program Savings (kWh)	Peak Savings per Unit (kW)	Peak Savings per Household (kW)	Total Coincident Peak (kW)
Appliances	High Efficiency Clothes Washer	All	27	27	788	788	21,272	0.023	0.023	1
	Microwave	All	2	2	162	162	325	0.000	0.000	0
	Refrigerators	Single Family	10,728	10,728	740	740	7,936,082	0.126	0.126	1,349
		Multifamily	5,296	5,296	580	580	3,069,686	0.099	0.099	522
		Mobile Homes	1,297	1,297	735	735	952,804	0.125	0.125	162
Domestic Hot Water	Faucet Aerator	Single Family	1,169	2,348	19	37	43,764	0.004	0.008	10
		Multifamily	2,348	4,052	0	0	0	0.000	0.000	0
		Mobile Homes	239	480	17	35	8,270	0.004	0.008	2
	Low Flow Shower Head	Single Family	1,004	1,344	46	62	62,370	0.010	0.014	14
		Multifamily	2,097	2,233	0	0	0	0.000	0.000	0
		Mobile Homes	166	213	55	71	11,786	0.012	0.016	3
	Water Heater Blanket	Single Family	301	283	98	92	27,610	0.021	0.020	6
		Multifamily	286	282	0	0	0	0.000	0.000	0
		Mobile Homes	20	20	261	261	5,218	0.057	0.057	1
	Water Heater Pipe Insulation	Single Family	378	1,397	2	6	2,237	0.000	0.001	0
		Multifamily	475	1,442	0	0	0	0.000	0.000	0
		Mobile Homes	38	153	3	11	423	0.001	0.002	0
Enclosure	Air Sealing / Envelope (Cooling)	Single Family	33,021	179,549	11	61	2,024,431	0.000	0.000	0
		Multifamily	15,821	62,589	18	71	1,124,736	0.000	0.000	0
		Mobile Homes	2,697	12,203	15	67	181,879	0.000	0.000	0
	Air Sealing / Envelope (Heating)	All	51,539	254,341	0	0	0	0.000	0.000	0
	Attic Insulation (Cooling)	Single Family	4,325	4,941,650	0	101	435,424	0.000	0.057	247
		Multifamily	612	499,378	0	103	63,249	0.000	0.048	30

	Attic Insulation (Heating)	All	5,449	5,500,892	0	0	0	0.000	0.000	0
HVAC	Central A/C Replacement	Single Family	809	831	72	74	59,927	0.085	0.087	70
		Multifamily	862	867	0	0	0	0.000	0.000	0
		Mobile Homes	132	134	0	0	0	0.000	0.000	0
	Evaporative Coolers (Installation)	Single Family	2,131	2,131	547	547	1,165,757	0.569	0.569	1,212
		Multifamily	150	150	540	540	81,049	0.689	0.689	103
		Mobile Homes	170	170	523	523	88,850	0.857	0.857	146
	Evaporative Coolers (Replacement)[34]	Single Family	-	-	547	547	-	0.569	0.569	-
		Multifamily	-	-	540	540	-	0.689	0.689	-
		Mobile Homes	-	-	523	523	-	0.857	0.857	-
	Room A/C Replacement[35]	Single Family	-	-	72	74	-	0.085	0.087	0
Lighting	Compact Fluorescent Lights (CFLs)	Single Family	43,352	302,136	13	93	4,040,451	0.001	0.010	444
		Multifamily	22,547	137,768	15	93	2,101,403	0.002	0.010	231
		Mobile Homes	4,062	27,562	14	93	378,583	0.002	0.010	42
	Exterior Hard wired CFL fixtures	Single Family	41,718	96,780	148	147	4,180,766	0.016	0.016	460
		Multifamily	19,049	43,562	319	315	1,908,994	0.035	0.035	210
		Mobile Homes	4,010	9,875	1,335	1,214	401,862	0.147	0.134	44
	Interior Hard wired CFL fixtures[36]	Single Family	-	-	45	107	-	0.005	0.012	-
		Multifamily	-	-	44	102	-	0.005	0.011	-

[34] Program level tracking data did not distinguish between evaporative cooler installation and evaporative cooler replacement; pre-unit and per-household savings are assumed to be the same for both measures.

[35] The regression analysis did not distinguish between central and room air conditioners; pre-unit and per-household savings are assumed to be the same for both measures.

[36] The regression analysis did not distinguish between interior and exterior hard-wired fixtures; pre-unit and per-household savings are assumed to be the same for both measures.

		Mobile Homes	-	-	41	100	-	0.004	0.011	-
	Occupancy Sensor	Single Family	10,944	15,293	40	40	610,191	0.004	0.006	61
		Multifamily	4,377	5,230	40	40	208,677	0.004	0.005	21
		Mobile Homes	532	579	40	40	23,102	0.004	0.004	2
	Torchiere	Single Family	6,412	6,324	204	204	1,289,400	0.020	0.020	125
		Multifamily	1,373	1,355	204	204	276,271	0.020	0.020	27
		Mobile Homes	1	1	204	204	204	0.020	0.020	0
Maintenance	Central A/C Tune-up	Single Family	14	14	67	67	938	0.100	0.100	1
		Multifamily	1	1	48	48	48	0.070	0.070	0
		Mobile Homes	7	5	69	69	346	0.110	0.079	1

Table 86. SCE Electric Savings

Measure Category	Measure Name	House Type	# of Households	# of Units Installed	Savings per Unit (kWh)	Savings per Household (kWh)	Total Program Savings (kWh)	Peak Savings per Unit (kW)	Peak Savings per Household (kW)	Total Coincident Peak (kW)
Domestic Hot Water	Refrigerators	Single Family	11,003	11,003	740	740	8,139,515	0.126	0.126	1,384
		Multifamily	3,362	3,362	580	580	1,948,694	0.099	0.099	331
		Mobile Homes	1,414	1,414	735	735	1,038,754	0.125	0.125	177
	Faucet Aerator	Single Family	88	190	16	35	3,103	0.004	0.008	1
		Multifamily	70	123	0	0	0	0.000	0.000	0
		Mobile Homes	25	54	16	35	876	0.004	0.008	0
	Low Flow Shower Head	Single Family	116	156	40	53	6,177	0.009	0.012	1
		Multifamily	75	88	0	0	0	0.000	0.000	0
		Mobile Homes	23	27	65	76	1,743	0.014	0.017	0
	Water Heater Blanket	Single Family	27	28	67	69	1,863	0.015	0.015	0
		Multifamily	4	4	0	0	0	0.000	0.000	0
		Mobile Homes	15	15	35	35	526	0.008	0.008	0
	Water Heater Pipe Insulation	Single Family	37	39	22	23	865	0.005	0.005	0
		Multifamily	15	15	0	0	0	0.000	0.000	0
		Mobile Homes	19	19	13	13	244	0.003	0.003	0
Enclosure	Air Sealing / Envelope (Cooling)	Single Family	153	912	16	98	14,958	0.000	0.000	0
		Multifamily	124	670	14	77	9,585	0.000	0.000	0
		Mobile Homes	11	19	57	98	1,075	0.000	0.000	0
	Air Sealing / Envelope (Heating)	All	288	1,601	0	0	0	0.000	0.000	0
HVAC	Central A/C Replacement	Single Family	1,959	2,003	85	87	171,085	0.091	0.093	182
		Multifamily	148	148	0	0	0	0.000	0.000	0
		Mobile Homes	406	420	0	0	0	0.000	0.000	0
	Evaporative	Single Family	5,760	5,760	490	490	2,820,903	0.565	0.565	3,253

	Coolers (Installation)									
		Mobile Homes	967	967	469	469	453,493	0.777	0.777	751
	Evaporative Coolers (Replacement) [37]	Single Family	-	-	490	490	-	0.565	0.565	-
		Mobile Homes	-	-	469	469	-	0.777	0.777	-
	Heat Pump Replacement	Single Family	40	40	639	639	25,560	0.287	0.287	11
		Multifamily	7	7	721	721	5,044	0.271	0.271	2
		Mobile Homes	18	18	1,055	1,055	18,984	0.580	0.580	10
	Room A/C Replacement[38]	Single Family	0	0	85	87	0	0.091	0.093	0
Lighting	Compact Fluorescent Lights (CFLs)	Single Family	22,517	84,946	25	93	2,098,607	0.003	0.010	231
		Multifamily	3,320	12,015	26	93	309,427	0.003	0.010	34
		Mobile Homes	3,405	12,765	25	93	317,349	0.003	0.010	35
	Exterior Hard wired CFL fixtures	Single Family	395	504	79	100	39,585	0.009	0.011	4
	Interior Hard wired CFL fixtures[39]	Single Family	-	-	79	100	-	0.009	0.011	-
	Torchiere	Single Family	1,332	1,322	191	191	252,502	0.020	0.020	26
		Multifamily	188	188	191	191	35,908	0.020	0.020	4
		Mobile Homes	214	214	191	191	40,874	0.020	0.020	4
Maintenance	Central A/C Tune-up	Single Family	16	16	955	955	15,272	0.575	0.575	9
Miscellaneous	Pool Pumps	Single Family	719	719	0	0	0	0.000	0.000	0

[37] Program level tracking data did not distinguish between evaporative cooler installation and evaporative cooler replacement; pre-unit and per-household savings are assumed to be the same for both measures.

[38] The regression analysis did not distinguish between central and room air conditioners; pre-unit and per-household savings are assumed to be the same for both measures.

[39] The regression analysis did not distinguish between interior and exterior hard wired fixtures; pre-unit and per-household savings are assumed to be the same for both measures.

Table 87. SCG Electric Savings

Measure Category	Measure Name	House Type	# of Households	# of Units Installed	Savings per Unit (kWh)	Savings per Household (kWh)	Total Program Savings (kWh)	Peak Savings per Unit (kW)	Peak Savings per Household (kW)	Total Coincident Peak (kW)
Enclosure	Air Sealing / Envelope (Cooling)	Single Family	5,615	37,260	13	84	470,308	0.000	0.000	0
		Multifamily	370	1,750	15	71	26,218	0.000	0.000	0
		Mobile Homes	320	3,060	10	99	31,645	0.000	0.000	0
	Air Sealing / Envelope (Heating)	All	6,305	42,070	0	0	0	0.000	0.000	0
	Attic Insulation (Cooling)	Single Family	612	534,330	0	143	87,728	0.000	0.094	58
		Multifamily	4	2,173	0	108	434	0.000	0.062	0
	Attic Insulation (Heating)	All	3,781	3,244,170	0	0	0	0.000	0.000	0

Table 88. SDG&E Electric Savings

Measure Category	Measure Name	House Type	# of Households	# of Units Installed	Savings per Unit (kWh)	Savings per Household (kWh)	Total Program Savings (kWh)	Peak Savings per Unit (kW)	Peak Savings per Household (kW)	Total Coincident Peak (kW)
Appliances	Microwave	All	265	265	698	698	185,076	0.000	0.000	0
	Refrigerators	Single Family	1,485	1,497	734	740	1,098,535	0.125	0.126	187
		Multifamily	690	694	576	580	399,940	0.098	0.099	68
		Mobile Homes	60	63	700	735	44,077	0.119	0.125	7
Domestic Hot Water	Faucet Aerator	Single Family	7,089	15,501	15	34	240,101	0.003	0.007	53
		Multifamily	8,222	17,373	0	0	0	0.000	0.000	0
		Mobile Homes	156	419	14	39	6,057	0.003	0.009	1
	Low Flow Shower Head	Single Family	7,121	9,804	38	52	373,101	0.008	0.012	82
		Multifamily	7,752	9,995	0	0	0	0.000	0.000	0
		Mobile Homes	165	258	36	57	9,412	0.008	0.013	2
	Thermostatic Shower Valve	All	2,472	3,545	399	572	1,414,455	0.000	0.000	0
	Water Heater Blanket	Single Family	927	931	34	34	31,571	0.007	0.007	7
		Multifamily	148	150	0	0	0	0.000	0.000	0
		Mobile Homes	31	31	26	26	796	0.006	0.006	0
	Water Heater Pipe Insulation	Single Family	336	1,258	4	13	4,488	0.001	0.003	1
		Multifamily	71	200	0	0	0	0.000	0.000	0
		Mobile Homes	38	152	1	3	113	0.000	0.001	0
	Water Heater Repair/Replace ment	All	1	1	0	0	0	0.000	0.000	0
Enclosure	Air Sealing / Envelope (Cooling)	Single Family	6,728	57,127	6	48	323,944	0.000	0.000	0
		Multifamily	7,642	23,859	16	50	379,811	0.000	0.000	0
		Mobile Homes	163	760	11	51	8,376	0.000	0.000	0
	Air Sealing / Envelope	All	14,533	81,746	0	0	0	0.000	0.000	0

	(Heating)								
	Attic Insulation (Cooling)	Single Family	539	582,414	0	91	49,303	0.000	0.064	35
		Multifamily	8	8,674	0	91	727	0.000	0.069	1
	Attic Insulation (Heating)	All	547	593,394	0	0	0	0.000	0.000	0
HVAC	Central A/C Replacement	Single Family	116	116	39	39	4,485	0.050	0.050	6
		Multifamily	280	280	0	0	0	0.000	0.000	0
		Mobile Homes	10	10	0	0	0	0.000	0.000	0
	Room A/C Replacement[40]	Single Family	-	-	39	39	-	0.050	0.050	-
		Multifamily	-	-	0	0	-	0.000	0.000	-
		Mobile Homes	-	-	0	0	-	0.000	0.000	-
Lighting	Compact Fluorescent Lights (CFLs)	Single Family	8,435	47,289	17	93	786,151	0.002	0.010	86
		Multifamily	8,759	43,476	19	93	816,348	0.002	0.010	90
		Mobile Homes	165	1,035	15	93	15,378	0.002	0.010	2
	Interior Hard wired CFL fixtures	Single Family	3,250	8,473	38	100	325,698	0.004	0.011	36
		Multifamily	1,692	3,166	54	100	169,564	0.006	0.011	19
		Mobile Homes	91	286	32	100	9,120	0.004	0.011	1
	LED Night Lights	Single Family	4,349	13,341	10	10	136,345	0.000	0.000	0
		Multifamily	5,616	15,031	10	10	153,617	0.000	0.000	0
		Mobile Homes	110	329	10	10	3,362	0.000	0.000	0
	Torchiere	Single Family	2,123	3,086	191	191	589,426	0.020	0.029	62
		Multifamily	2,552	3,619	191	191	691,229	0.020	0.028	72
		Mobile Homes	50	81	191	191	15,471	0.020	0.032	2
Maintenance	Central A/C Tune-up	Single Family	32	32	223	223	7,134	0.000	0.000	0
		Mobile Homes	8	8	215	215	1,720	0.000	0.000	0

[40] The regression analysis did not distinguish between central and room air conditioners; pre-unit and per-household savings are assumed to be the same for both measures.

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

Full Model Results

This evaluation of the California Low-Income Energy Efficiency Program builds upon previous evaluations. Like earlier studies, the estimates of energy savings from the installed program are obtained using a fixed effects regression model analyzing the full population of participants with usable billing records.

Table 89 shows a comparison of average household savings estimates from the PY2009 and previous impact evaluations. In general, the impact estimates from the PY2009 are lower than those found in the PY2005 evaluation, even though the same general method for estimating savings and choosing a final model was used in both evaluations (and conducted by several of the same researchers). The current impact estimates are within the range found in previous studies, however.

Table 89. Summary Savings Estimates (Average Annual Savings Per Household)

	Average Annual Pre-Installation Energy Consumption[41]	PY2009 Evaluation	PY2005 Evaluation	PY2002 Evaluation	PY2001 Evaluation	PY2000 Evaluation
Electric Savings (kWh)						
Combined Utilities[42]	5,752	330	423	366	213	175
PG&E	5,933	402	433	399	236	240
SCE	5,819	247	435	286	203	153
SDG&E	4,580	303	342	370	215	89
Gas Savings (Therms)						
Combined Utilities	318	9	18	8	18	24
PG&E	331	9	19	9	18	28
SDG&E	260	8	14	4	13	13
SCG	317	11	17	17	20	26

The lower savings relative to 2005 may be a reflection of the inherent difficulty in estimating savings from a billing regression models for residences where expected savings values are a small fraction of total energy use and where there can be substantial variation across households and program years (such as economic conditions) that cannot be entirely controlled for in the model. Additionally, some of the lower impact estimates may be a sign of diminishing savings available. Program savings may be less because the most opportune homes have already been treated and households have over the years adopted some of the measures, such as CFLs, previously supplied.

[41] This column reflects the average annualized pre-installation kWh consumption for the 2008 participants who were included in the population regression analysis sample.

[42] Combined utility average consumption were calculated from the data set used for the regression analyses. Household savings were derived by summing the savings separately for each of the four utilities and dividing by the total number of participants.

A change in weather conditions relative to 2005 is a third possible explanation of the lower impact estimates. A closer examination of the weather conditions in the current evaluation indicates that a shift in participation to milder climate conditions may explain at least some of the decrease in estimated savings relative to the 2005 impact evaluation. This was evidenced by a substantial shift in participation to milder climate zones for some weather-dependent measures as well as lower HDDs experienced in the current evaluation for some high usage customers installing these measures.

While LIEE participants tend to use less energy than the average residential utility customer[43], this analysis clearly demonstrates that there are some high users among LIEE participant and the savings in these homes can be substantial, especially when these homes are located in the more extreme climate areas. This finding applies to some potentially marginal measures including evaporative coolers and heating system repair and replacement, as well as more common and stable measures such as refrigerator replacement.

It is also clear from the estimation of savings by climate zone that savings are considerable in the more extreme climates. The wide geographic range of the CEC climate zones evens out local variations in temperatures, and it is highly likely that homes in some areas in climate zones 10 and 15 may well have higher or lower savings. Specifying homes eligible for specific weather-sensitive measures based on CEC climate zone may eliminate some participants with potentially cost effective installations.

We have generated two gas models, one that specifically identifies takeback effects and one that does not.[44] The results identify that some takeback effect is occurring, i.e., that participants are using their heating equipment more now that it is more efficient. We are presenting our overall results without the takeback effects because these results are more comparable to previous evaluation results that only identified energy savings.

Recent articles about takeback have suggested that the issue is so large as to completely negate the value of the efficiency efforts. That is certainly not evidenced in these results, though takeback is substantial. It has always been accepted that a certain amount of takeback would happen, especially when treating low-income households. The higher than normal takeback effect happens here because households are using very little or no gas for heating in the pre-treatment period. The LIEE upgrades allow participants to increase heating use by making equipment more efficient, and in some cases fixing equipment that was not previously used. In some cases, this increase is accompanied by a decrease in supplemental heating using wood or electric heaters and ovens. This analysis does not fully track all of these trade-offs and their ultimate effects on carbon emissions or in overall health and safety benefits. These takeback and other non-energy benefits may be sufficient to justify continuation of some measures that fail a strict energy-only cost effectiveness test.

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[43] For a discussion of the average energy usage for low-income customers and a comparison with the average for California residents, see pp. 42-45 of the 2005 evaluation report *Impact Evaluation 2005 California Low Income Energy Efficiency Program Final Report* (August 19, 2008).

[44] It was not possible to implement the same strategy for the electric model due to the relatively small percentage of the LIEE population who received electric heating- or cooling-related measures.

Phone and On-site Heating and Cooling Models

This study was designed to try to explain the magnitude of the savings amounts for major heating and cooling measures. Previous impact evaluations found smaller impacts for major heating- and cooling-related measures than expected, especially for natural gas measures. Because these measures represent a substantial portion of LIEE expenditures, the 2009 LIEE evaluation included several enhancements over earlier LIEE evaluations, such as focusing on building more complete models of the heating and cooling use and savings in treated homes. These enhancements involved both broader data collection and analysis. The data collection efforts added additional questions on heating and cooling use in the telephone and on-site survey and detailed examination of the home characteristics and heating and cooling system components in the on-site survey.

The data collection phase of this study included a phone survey of 1,500 participants and an on-site assessment of 400 participant households. In addition, this study also added a phone survey of 1,500 non-participant households. The phone surveys included a battery of questions on household demographics, energy use, influence of the education session, and program satisfaction similar to those used in previous years. This year's surveys also added an extensive battery on the detailed use of heating and cooling equipment before and after LIEE interaction.

The on-site data collection done as part of the 2005 evaluation was focused on measuring savings from water heating conservation and lighting education measures. That collection instrument included measurement of showerhead flow rates and lighting that we did was not included in this year's collection. Instead, the auditors collected measurement of square footage of windows, walls, floor area, and attic areas. The auditor also collected detailed information on all heating and cooling equipment. Finally, the auditor asked detailed questions on equipment use and occupancy changes.

The real achievement of this round of modeling is the inclusion of some of the behavior elements in the phone and on-site analyses that helped corroborate the findings from the population billing regression. Data regarding prior use of heating equipment is a telling factor in explaining energy savings. Interestingly, data on the physical characteristics of the homes did not prove to be as useful in defining energy savings. Given that the most useful questions were behavioral in nature, it does not appear as though on-site assessments will be required to duplicate the results should this type of study be desired in the future.

The inclusion of use variables helps explain why the full model results are not showing any measureable savings for furnace repairs and replacements. The primary explanation for why there was no measurable savings from furnace repairs and replacements is that most homes use very little heating. This is supported by the results of the phone and telephone survey. In general, homes that received a furnace repair or replacement increased their household use after the treatment. For the majority of households, the use of heating is small and the other measures such as insulation resulted in little or no energy savings.

The phone and on-site survey results also show that the program education is having only a small effect on participants, with only 30 percent of on-site survey respondents continuing to follow through with recommendations received during the LIEE visit. This result is consistent with the findings of the PY2005 evaluation.

9.2 Recommendations

The full data population model represents the best estimate of measure savings. The question arises as to which of the model using the on-sites sample, telephone sample, or full population supplies the best estimate of measure savings. From our perspective, the full population model is the best estimate of measure saving because it alone includes a full set of participants and reflects overall savings. The smaller models (because they have additional behavioral and house characteristic data) often help explain why some savings estimates are what they are. For example the on-site model indicated that previous use of heaters and changes in heater use were major factors in explaining the savings estimates from the full population model. While we did not have the detailed information about previous use, we were able to restructure the full data model to define usage categories that proved to be an effective means of including previous use as a factor in the final model.

Using the 2008 participants to estimate impacts for PY2009 was also useful in that it allowed the evaluation to proceed without waiting for a full year of post-installation data for 2009 participants. In the future, we recommend that this approach be adopted, as long as the years covered are reasonably similar with no substantial differences in economic conditions and/or program delivery.

Surveys and on-sites are useful, but their cost limits their applicability. This evaluation included the most extensive data collection and modeling effort to date in an effort to quantify program impacts from a variety of sources. While this effort yielded useful information, the on-site and phone survey regressions ultimately did not improve upon the prior method of using the full LIEE participant dataset to estimate impacts. As the phone survey and on-site surveys are both time and budget intensive, future evaluators should think twice before using them as a primary means to develop billing regression models with the expectation that they will improve upon the population regression model.

Although we could not improve upon the population regression model, the phone and on-site data did help confirm findings from the regression models. Data from the on-site survey results that confirm that treated households do not all behave as expected from engineering assumptions. Some households were found to not heat or cool when or as often as expected. Others were found to increase usage after the new equipment is installed often because the systems were not previously used and were subsequently used more after repair or replacement. As it turned out, the physical measurements collected by the on-site auditors proved to be less useful than the behavioral related questions collected by both the phone and on-site surveys. If another round of detailed analysis is attempted, it will be possible to use the phone survey to collect the battery of behavioral questions. This would eliminate the need for on-sites altogether.

Continue targeting evaporative coolers in the hottest climates and consider additional education. Savings for evaporative coolers could be improved through additional education. The phone and on-site survey respondents indicated that many of them did not realize that the evaporative coolers should be operated with the windows open and that they should not run their air conditioners as the same time. Some participants are also still continuing to use their existing cooling systems in addition to the evaporative cooler. Better education on proper use of the evaporative cooler should increase savings for these customers.

Program should restrict furnace repairs and replacements to households with large weather dependent loads. The program already targets the hottest areas for installing evaporative coolers. A similar strategy needs to be adopted for furnace repair/replacements. While any cooling application is likely to have peak summer demand benefits even if there are few kWh's saved, there is no equivalent benefit in treating homes that use small amounts gas for heating. The low estimates for gas heating savings from the population regression model is consistent with information from both surveys and the PY2005 evaluation. Participants receiving a furnace replacement or repair indicate that they use the new system more often than before. There is also evidence that there are supplemental heating systems used, which would further erode savings from this measure. Consequently, it is not surprising that these customers use their heating systems more after participating, which was reflected in the billing regression model for these measures. The on-site results also provided additional insights into how heating and cooling equipment are being used, such as limited cooling equipment use in some areas with milder climates and manual control of these systems when they are used. These behavioral findings help support some of the lower impacts estimated for these measures from the billing regression.

Targeting more extreme climate zones will increase savings for weather-dependent measures. While this is a somewhat obvious recommendation, a pronounced shift toward milder climates in the current evaluation is a key factor in explaining the lower impact estimates relative to the 2005 evaluation. Focusing installations in more extreme climates with higher heating and/or cooling loads will increase savings for these measures and help improve program cost effectiveness.

APPENDICES

Appendices are included as separate documents and consist of the following:

Appendix A: Survey Instruments (Phone and On-site)

Appendix B: Phone Survey Responses

Appendix C: Phone Survey Regression Results

Appendix D: Detailed Impact Tables

Appendix E: Memo on Data Screening