1993 Residential Energy-Use Profiles Program Evaluation Study

Study ID No. 528 (B)

Submitted to:

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Executive Summary

1.1 Introduction

This Executive Summary describes an evaluation of the persistence of energy savings associated with 1993 Energy-Use Profiles Program (EUPP) offered by Southern California Edison Company (SCE or Edison). The EUPP is a component of the SCE Residential Energy Management Services Program. The study was conducted by Regional Economic Research, Inc. (RER) under a contract with Edison. Shahana Samiullah acted as Edison's Project Manager. Ms. Samiullah's work on the first-year evaluation of the program (Samiullah, 1995)[1] served as the basis for much of RER's analysis.

1.2 Background and Objectives

The EUPP is a mail or telephone bill disaggregation program designed to help SCE's customers use home energy more efficiently. Using either a mail or telephone format, customers provide information on structural factors, current stocks of appliances, inventories of conservation measures, current behavioral practices, and economic and demographic characteristics. Participants then receive bill decomposition graphs, site-specific savings recommendations, and information on other programs.

The EUPP is the third residential bill disaggregation program offered by SCE since 1986. From 1986 through April, 1989, SCE offered the Customer Power Profile. This program provided customers with graphs of their billing history and appliance-specific annual energy use using a generic computer analysis of a mail-in questionnaire. The Enchanced Customer Power Profile replaced this program in mid-1989 and was available until the end of 1992. This program introduced sophisticated computer analyses, engineering models, actual weather, and customer-specific rates to produce household-specific results. In 1993, customer-specific recommendations on energy saving measures and practices and a telephone audit option were added, and the program was renamed the Energy Use Profiles Program.

[1] *Southern California Edison 1993 Energy Use Profile Impact Evaluation Study*, Measurement and Evaluation Report #508(A), prepared by Shahana Samiullah, Measurement & Evaluation Marketing Organization Southern California Edison, March 1995

The objective of this study was to conduct a second-year impact study of the 1993 EUPP. This study focuses on the persistence of impacts for 1993 participants. This analysis was facilitated by the California Public Utility Commission's (CPUC) grant of a waiver of the first-year impact study of SCE's 1995 Energy-Use Profile Program.

1.3 Previous Analysis

SCE conducted a first-year impact study of the 1993 EUPP (Samiullah, 1995). Net program savings were estimated for seven end-use categories using a form of billing analysis called realization rate analysis. This technique utilizes program data, engineering estimates of savings from the adoption of program recommendations, billing histories, weather data, and information on actual adoptions. Data on actual program adoptions were collected with a follow-up survey of 2,222 participants and 1,369 nonparticipants.

This previous study estimated net per-participant annual savings of 219 kWh. Roughly 50% of the savings was attributable to the adoption of refrigeration recommendations. Water heating, freezer, and space heating adoptions accounted for around 13%, 12% and 9%, respectively. The remaining savings were split between air conditioning, laundry, and spa/pool end uses.

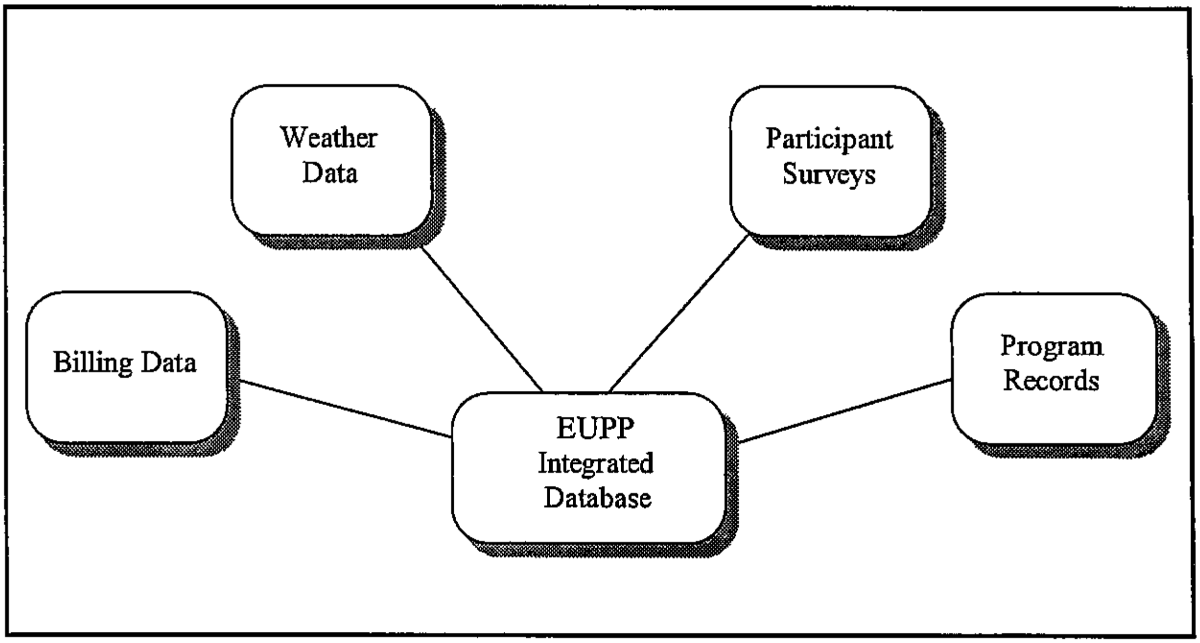
1.4 Data

The second-year impact evaluation of the 1993 EUPP requires construction of an integrated database. This database is an updated version of the database used in the 1993 Energy Profile Impact Evaluation Study (Samiullah, 1995). In particular, the existing database was updated with the billing and weather data required to evaluate second-year impacts. Figure 1-1 provides an overview of the information used to construct the database. The key elements include the following:

- Existing Impact Evaluation Database:
  - Participant survey data
  - Program records
  - Engineering estimates of end-use consumption for participants
  - Engineering estimates of savings for each measure and practice by participant
  - Average end-use annual energy consumption estimates (UECs)
  - 1992:1-1994:9 billing data
  - 1992:1-1994:9 weather data
- Updated Billing Data (1994:9-1996:7), and
- Updated Weather Data (1994:9-1996:7).

Each of these elements is discussed in detail in the following sections.

Figure 1-1: Overview of Database



1.5 Persistence Analysis Methodology

The persistence analysis methodology was designed to be consistent with the approach taken by SCE to estimate first-year savings. The approach involved the following steps:

- First, some minor changes in the specific modeling methodology used in the first-year impact study were made. These changes involved the adjustment of engineering estimates of usage and savings for variations in weather conditions, expansions of the model to include a few additional variables designed to control for other changes at the sites in question, screening of outliers, and the use of a deadband in the immediate post-audit period.
- Second, the data used to estimate the model were expanded to cover a second post-program year. This entailed the collection of additional billing and weather data, however, it did not necessitate the collection of any updated survey data.
- Third, the model was estimated using the expanded sample period. Savings variables were interacted with three measures of time—a linear time term, a logarithmic time term, and a binary variable representing the second year of the post-program year—in order to allow changes in savings over time.
- Finally, the expanded model was used to simulate the end-use impacts of the program for the first and second post-program periods.

1.6 Summary of Results

This analysis estimated first- and second-year savings by end use. Table 1-1 presents first- and second-year savings by end use for normal and actual weather. The results indicate an annualized first-year savings of 123 kWh per participant under normal weather conditions. This falls by 7% to just under 115 kWh in the second year. Other key findings include:

- Savings from measures and practices associated with all non-weather sensitive end uses show persistence of savings over the second year of the program. This is understandable, as the majority of adopted program recommendations are measures, as opposed to practices. For example, the majority of refrigeration- and freezer-related adoptions are replacement of primary units.
- The lack of persistence from space heating and air conditioning adoptions may be attributable to the mix of measures and practices. In particular, over 85% of space heating and just under 50% of air conditioning related adoptions were practices associated with changes in thermostat settings. This lack of persistence is consistent with the typical unreliability of self-reported conservation actions dealing with thermostat settings.
- Just over 77% of annual first-year savings is attributable to the adoption of refrigeration measures and practices. The lack of persistence of the weather sensitive end-use-related measures and practices causes this to climb to roughly 82% in the second year.
- Per-participant savings under normal and actual weather conditions differ by only about 1%. This is understandable, as weather conditions for the analysis period were very similar to normal weather conditions and weather sensitive end-use-related adoptions accounted for about 24% of savings.
- Estimated first-year savings from this study are roughly 56% of the estimates made in a previous SCE-sponsored study (Samiullah, 1995). The differences in estimated savings may be due to the expanded sample size and/or changes in the specification of weather adjustments to the engineering estimates of usage and savings.

Table 1-1: Annualized First- and Second-Year Savings (kWh per Participant)

	Actual Weather		Normal Weather	
End Use	First-Year Savings (kWh)	Second-Year Savings (kWh)	First-Year Savings (kWh)	Second-Year Savings (kWh)
Air Conditioning	.842	.204	.909	.217
Space Heating	1.448	1.440	1.444	1.392
Water Heating	.613	.613	.613	.613
Refrigeration	6.796	6.796	6.796	6.796
Freezers	.473	.473	.473	.473
Spa/Pool	.001	.001	.001	.001
Laundry	.050	.050	.050	.050
Monthly Savings	10.22	9.58	10.29	9.54
Annual Savings	122.67	114.91	123.43	114.49

2

Introduction

2.1 Introduction

This report describes an evaluation of the persistence of the 1993 Energy-Use Profiles Program (EUPP) offered by Southern California Edison Company (SCE). The EUPP is a component of the SCE Energy Management Services Program. The remainder of this section provides background on the program, reviews the previous analysis of the program's first-year savings, specifies project objectives, discusses data and methodology used in the study, and previews the rest of the report.

2.2 Background

The EUPP is a mail or telephone audit program designed to help SCE's customers use home energy more efficiently. Using either a mail or telephone format, customers provide information on structural factors, current stocks of appliances, inventories of conservation measures, current behavioral practices, and economic and demographic features. Participants then receive bill decomposition graphs, site-specific savings recommendations and information on other programs.

The EUPP is the third residential audit program offered by SCE since 1986. From 1986 through April, 1989, SCE offered the Customer Power Profile. This program provided customers with graphs of billing history and appliance-specific annual energy use using a generic computer analysis of a mail-in questionnaire. The Enchanced Customer Power Profile replaced this program in mid-1989 and was available until the end of 1992. This program introduced sophisticated computer analyses, engineering models, actual weather, and customer-specific rates to produce household-specific results.

In 1993, customer-specific recommendations on energy saving measures and practices and a telephone audit option were added, and the program was renamed the Energy-Use Profiles Program.

2.3 Previous Analysis

SCE conducted a first-year impact study of the 1993 EUPP (Samiullah, 1995). Net program savings were estimated for seven end-use categories using a form of conditional demand analysis called realization rate analysis. This technique utilizes program data, engineering estimates of savings from the adoption of program recommendations, billing histories, weather data, and information on actual adoptions. Data on actual program adoptions were collected with a follow-up survey of 2,222 participants and 1,369 nonparticipants.

This previous study estimated a net per program participant annual savings of 219 kWh. Roughly 50% of the savings is attributable to the adoption of refrigeration recommendations. Water heating, freezer, and space heating adoptions account for around 13%, 12% and 9%, respectively. The remaining savings were split between air conditioning, laundry, and spa/pool end uses.

2.4 Project Objectives

The objective of this study is to estimate the persistence of EUPP savings. This study focuses on the persistence of impacts for 1993 participants. This study was made possible by the California Public Utility Commission's (CPUC) grant of a waiver of the first-year impact study of SCE's 1995 Energy-Use Profile Program.

2.5 Data

The second-year impact evaluation of the 1993 EUPP requires construction of an integrated database. This database is an updated version of the database used in the 1993 Energy Profile Impact Evaluation Study (Samiullah, 1995). In particular, the existing database was updated with the billing and weather data required to evaluate second-year impacts. The key elements include the following:

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- Second, the data used to estimate the model were expanded to cover a second post-program year. This entailed the collection of additional billing data and weather data, however, it did not necessitate the collection of any updated survey data.
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- Finally, the expanded model was used to simulate the end-use impacts of the program for the first and second post-program periods.

2.7 Organization of Report

The remainder of the report is organized as follows:

- Section 3 describes the methodology of the analysis. This includes details on development of the integrated database used in the impact evaluation, model specification, and model estimation.
- Section 4 presents the results of the study. In particular, first-year results from this study are compared with the previous study, and second-year savings by end use are presented. Results are presented under actual and normal weather conditions.

3

Methodology

3.1 Introduction

This section discusses the development of the database and the methodology used to evaluate the second-year impacts of the 1993 Energy-Use Profiles Program (EUPP). This estimates the second-year *ex post* savings associated with DSM measures and practices offered through the 1993 EUPP. The database used to support the analysis is described in Section 3.2, while the billing analysis is presented in Section 3.3.

3.2 SCE Energy-Use Profiles Integrated Database

Overview

The second-year impact evaluation of the 1993 EUPP requires construction of an integrated database. This database is an updated version of the database used in the 1993 Energy Profile Impact Evaluation Study (Samiullah, 1995). In particular, the existing database is updated with the billing and weather data required to evaluate second-year impacts. Figure 3-1 provides an overview of the information used to construct the database. The key elements include the following:

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Each of these elements is discussed in detail in the following sections.

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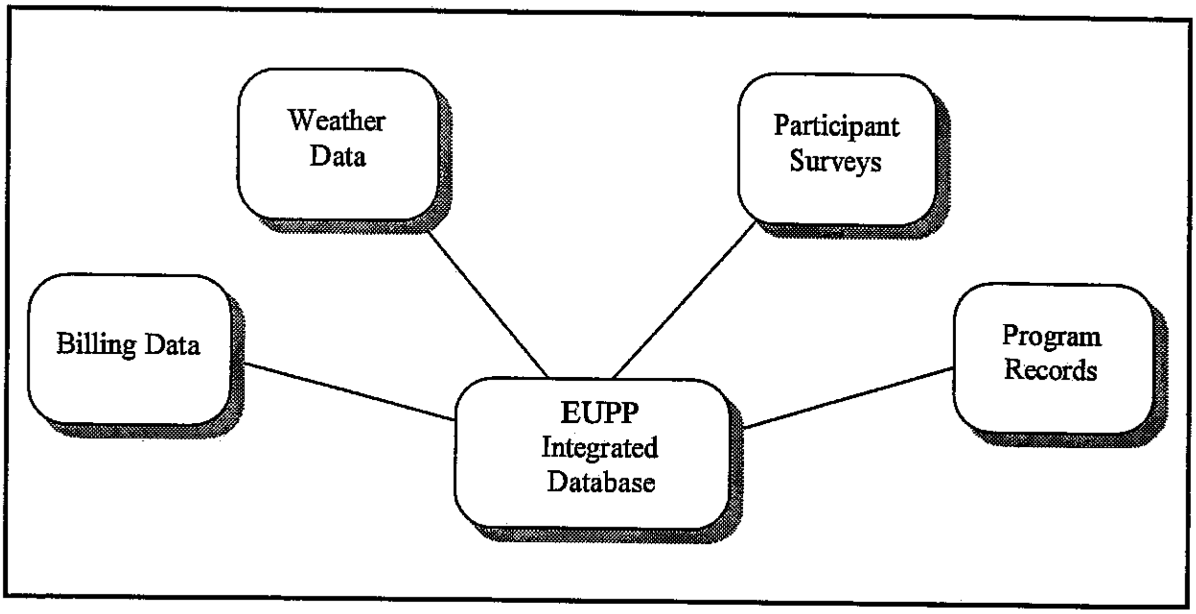

Pre-Existing EUPP Integrated Database

The pre-existing EUPP integrated database was constructed for use in the 1993 First-Year Impact Analysis. The key elements of this database include the following:

- Participant survey data,
- Program records,
- Engineering estimates of end-use consumption for participants,
- Engineering estimates of savings for each measure and practice by participant,
- Average end-use annual energy consumption estimates (UECs),
- 1992-1994:9 billing data, and
- 1992-1994:9 weather data.

A brief discussion of each of these elements follow.

Participant Survey Data. SCE conducted a follow-up survey of 1993 EUPP participants and a sample of nonparticipants in July, 1994. The survey collected information about the adoption and timing of the implementation of program recommendations. Further, data on changes in household appliance holdings, adoption of conservation measures not covered by the program, house remodels, and household demographics were gathered. The follow-up survey elicited responses from 2,222 participants and 1,369 nonparticipants. Details on sample methodology, questionnaire design, and survey protocol are presented as an appendix to the 1993 Energy-Use Profile Impact Evaluation Study (Samiullah, 1995).

Program Records. Information in program records helped to develop customer profiles on household demographics, appliance ownership, and housing characteristics. This data was gathered at the time of the energy audit. Again, details of the program files data is available in the 1993 study report.

Engineering Estimates of Participant End-Use Consumption. XENERGY developed engineering estimates of annual energy use for participants by end use during the course of the previous study. Two approaches allocated these annual estimates across months depending on whether the end use is weather or non-weather sensitive.

- ***Weather Sensitive End Uses.*** The engineering estimates for space heating and air conditioning were based on actual weather conditions for the 12 months preceding the audit. The annual estimates of heating and cooling loads were allocated across months by the ratio of the actual months heating and cooling degree days divided by the number of heating and cooling degree days in the 12 months preceding the audit. Specifically, the engineering estimate of cooling ($EECOOL_{it}$) for customer *i* and month *t* is defined as:

  $$(1)\quad EECOOL_{it} = \frac{ANNEECOOL_i \times CDD_t}{ANNCDD_i}$$

  where:

$EECOOL_{it}$	=	engineering estimate of air conditioning use
$ANNEECOOL_i$	=	annual estimate of air conditioning use
CDD_t	=	cooling degree days
$ANNCDD_i$	=	annual CDD for the 12 months preceding the audit

  A similar algorithm was used for space heating. The engineering estimate of space heating ($EEHEAT_{it}$) for customer *i* and month *t* is defined as:

  $$(2)\quad EEHEAT_{it} = \frac{ANNEEHEAT_i \times HDD_{it}}{ANNHDD_i}$$

  where:

$EEHEATL_{it}$	=	engineering estimate of air conditioning use
$ANNEEHEAT_i$	=	annual estimate of space heating use
HDD_t	=	heating degree days
$ANNHDD_i$	=	annual HDD for the 12 months preceding the audit

- ***Non-Weather Sensitive End Uses.*** Estimates of energy use for non-weather sensitive end uses were allocated to months by dividing the annual estimate by 12. The exception to this approach was water heating. *Monthly factors* based on residential load research data were derived to allocate water heating annual use across months. These factors, which are presented in Table 3-1, were used to account for the apparent seasonality in water heating loads.

- ***Calibration of Engineering Estimates.*** Insofar as the engineering estimates were calibrated to annual bills for the 12 months prior to the audit, a final calibration of the allocated monthly estimates was performed. In particular, monthly engineering estimates were calibrated on average to billing data for the pre-audit period. Table 3-2 presents the calibration factors by end use and month for space conditioning, water heating, and all other end uses.

Table 3-1: Water Heater Monthly Allocation Factors

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.21	1.17	1.12	1.04	.99	.94	.80	.75	.84	.93	1.04	1.18

Table 3-2: Calibration Factors for Engineering End-Use Estimates

End Use	Calibration Factor
Space Heating	
All months	.838
Winter months	.655
Air Conditioning	
All months	.850
Summer months	1.041
Water Heating	1.065
Other	1.046

Engineering Estimates of Savings from Participant DSM Measures and Practices. XENERGY also estimated engineering estimates of savings for each DSM measure and practice as part of the original study. These values were expressed as the percentage of annual use saved by each measure or practice. These percentages were then summed by end use and applied to each participant's annual end-use consumption. This same approach was used to allocate savings across months.

Average Annual Nonparticipant Energy Consumption Estimates by End Use. Engineering estimates of annual consumption were not available for nonparticipants in the previous or current study. In lieu of engineering estimates, estimates of annual use were derived using SCE service territory-specific UECs. Whole-house consumption for nonparticipants was then calculated as the sum of UECs for end uses owned by the customer.

Customer ownership data were derived from the follow-up survey. Table 3-3 presents the UEC values used in the analysis and the saturation of each end use.

Table 3-3: Appliance UECs and Saturation - Nonparticipants

Appliance	UEC	Saturation
Air Conditioning	1,308	48%
Space Heating	1,824	29%
Refrigerator	1,296	23%
Freezer	1,080	1%
Water Heater	3,864	9%
Pool/Spa	3,000	20%
Laundry	1,008	77%
Miscellaneous	2,328	100%

The annual UEC values were allocated to months for weather and non-weather sensitive end uses using the following methods:

- ***Weather Sensitive End Uses.*** Air conditioning and space heating are considered to be weather sensitive end uses. The annual UEC was allocated to months by the ratio of the product of house square footage and actual degree days to the mean of the product of house square footage and normal annual degree days. Specifically, the estimate of cooling ($NPCOOL_{it}$) for nonparticipant customer *i* and month *t*, is defined as:

$$(3)\quad NPCOOL_{it} = \frac{ACUEC_i \times SQFT_i \times CDD_t}{\overline{SQFT \times NORMCDD}}$$

where:

$NPCOOL_{it}$	=	estimate of air conditioning energy use
$ACUEC_i$	=	air conditioning UEC
$SQFT_i$	=	square footage of home
CDD_t	=	cooling degree days
$\overline{SQFT \times NORMCDD}$	=	mean of the product of SQFT and normal annual cooling degree days.

A similar algorithm was used for space heating. The engineering estimate of space heating ($NPHEAT_{it}$) for customer *i* and month *t* is defined as:

$$(4)\quad NPHEAT_{it} = \frac{HTUEC_i \times SQFT_i \times HDD_t}{\overline{SQFT \times NORMHDD}}$$

where:

$NPHEAT_{it}$	=	estimate of space heating energy use
$HTUEC_i$	=	space heating UEC
$SQFT_i$	=	square footage of home
HDD_t	=	heating degree days
$\overline{SQFT \times NORMCDD}$	=	mean of the product of square foot and normal annual heating degree days.

- ***Non-Weather Sensitive End Uses.*** Non-weather sensitive end-use UECs were allocated across months by dividing the annual UEC by 12.

Billing Data. The existing database contained billing data for the period January 1, 1992 through October, 1994. The billing cycle data were normalized to 30.4 days. To support the current study, SCE provided billing data for all participants and nonparticipants for the period from October, 1994 through September, 1996. These billing cycle data were also normalized to 30.4 days and then added to the integrated database.

Weather Data

A pre-existing database contained data on cooling and heating degree days derived by SCE staff using 15-minute interval temperature readings. For purposes of this analysis, RER used a simplified approach to calculate degree days based on daily high and low temperatures. For this approach, SCE provided RER with historical daily minimum and maximum temperatures. The historical period covers the period January, 1988 through October, 1996. These data were then used to construct daily heating (base 60°) and cooling (base 70°) degree days. These data were cumulated and merged with other database components by SCE weather station and reconciled to billing cycle using read dates. These data were then normalized to a 30.4 day billing cycle.

In addition, daily minimum and maximum temperatures were used to compute normal HDD and CDD for use in weather-normalizing weather sensitive end-use savings. The normal weather data are computed as the averages of heating and cooling degree days over the eight year period which the SCE weather database spans.[1]

Figure 3-2 depicts the actual cooling and heating degree days averaged over all SCE weather stations represented in the evaluation sample during 1993, 1994, and 1995. To depict the

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[1] Heating and cooling degree days are computed as follows:

CDD base 70 = max{0, (Daily Average Temperature - 70) }.

HDD base 60 = max{0, (60 - Daily Average Temperature) }.

Daily Average Temperature = (Daily Max. Temperature + Daily Min. Temperature)/2.

variation of weather conditions across the SCE service territory, Figure 3-3 and Figure 3-4 present the normal annual cooling and heating degree for each weather station, respectively. As shown by these graphs, the SCE weather zones represent a fairly wide range of weather conditions.

Weather data was merged with other database components by SCE weather station account numbers and read dates.

Figure 3-2: Average Cooling and Heating Degree Days

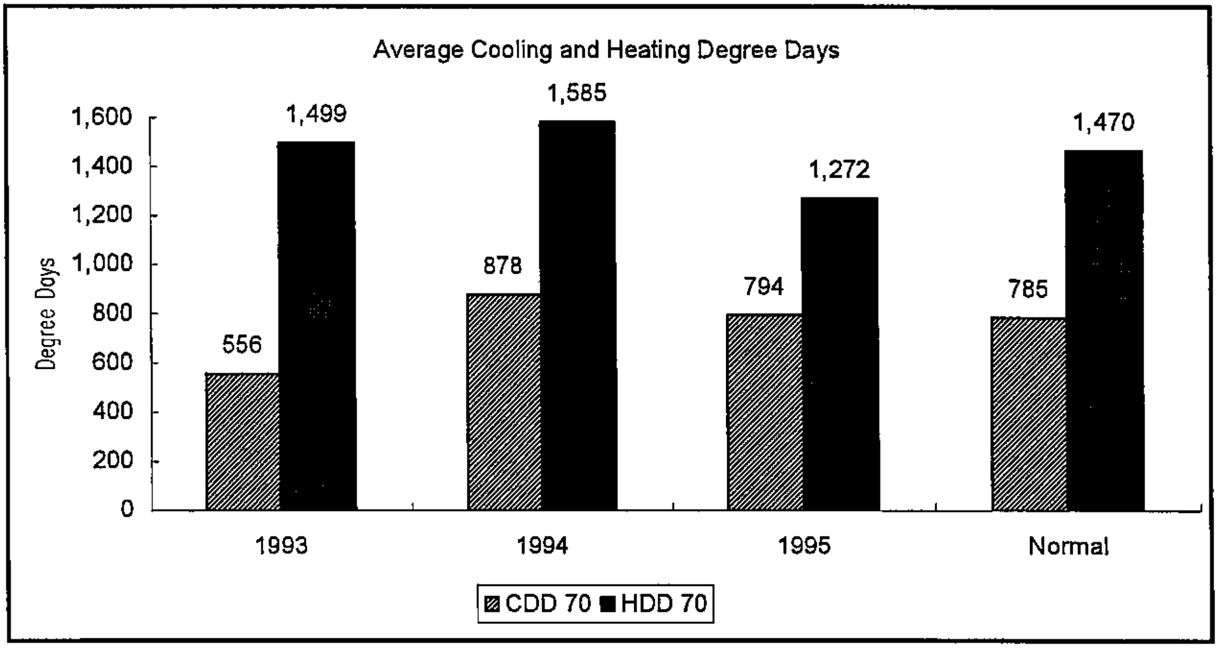


Figure 3-3: Normal Weather Cooling Degree Days

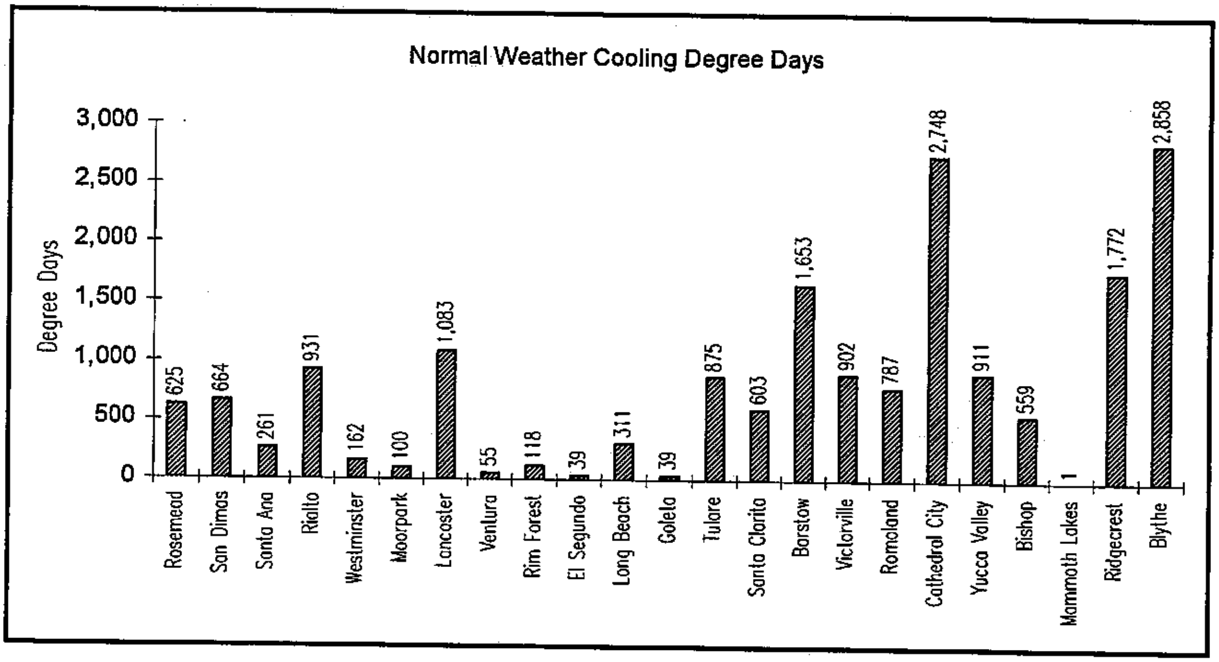
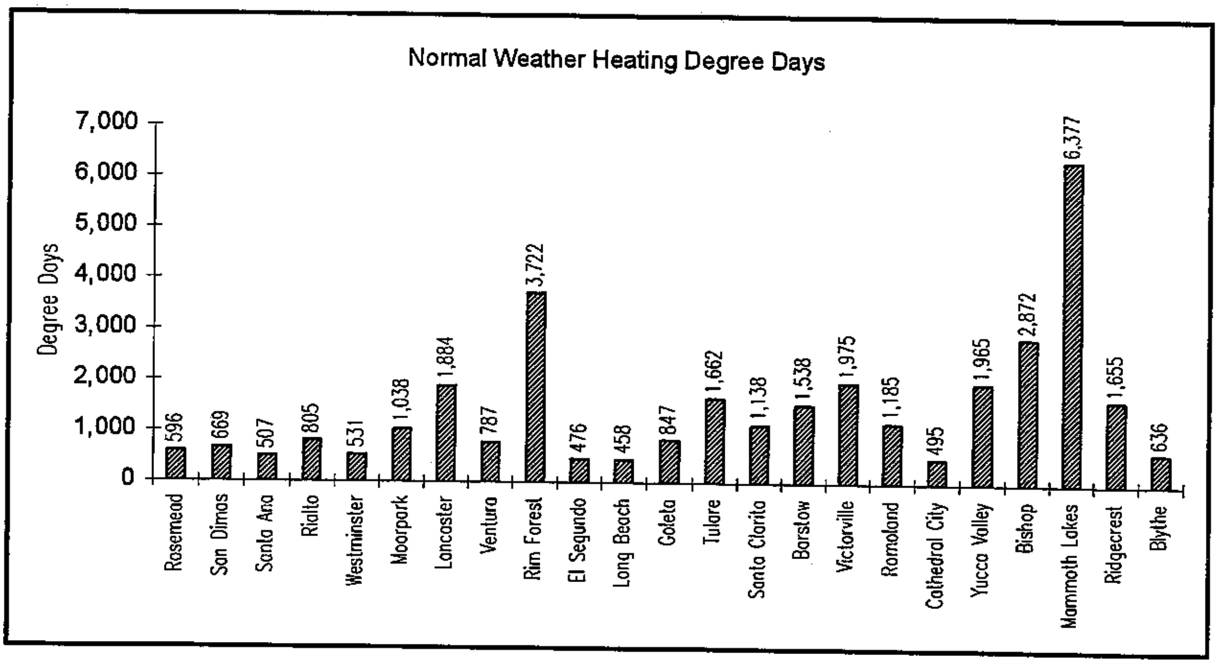


Figure 3-4: Normal Weather Heating Degree Days



3.3 Impact Analysis

Overview

The evaluation of the second-year impacts of the 1993 EUPP entails the extension of SCE's evaluation of the program's first-year impacts (Samiullah, 1995). The earlier SCE study relied on a realization rate approach that relates changes in energy consumption to conservation activities and a series of other factors. This technique provides an excellent means of taking advantage of the best features of both conditional demand analysis and engineering algorithms. Conservation impacts are represented in the model by a set of *ex ante savings variables* based on preliminary engineering calculations. Other variables are included to control for changes in weather conditions, site square footage, occupancy, household size, and other appliance stocks.

In order for realization rate analysis to be superior to change form conditional demand, the engineering estimates must be reasonably well correlated with actual impacts across customers. This does not mean that *ex ante* estimates have to be equal to actual impacts, but rather that they contain some information relating to these impacts. If *ex ante* estimates were always twice as high as actual savings for households, for instance, these estimates would add considerable information to the estimation of actual savings. On the other hand, if the *ex ante* estimates are totally uncorrelated with actual savings, they would add nothing to the estimation of impacts and could actually bias estimated savings downward. Since the ex ante estimates were based on the application of reasonable engineering algorithms to site specific data, the realization rate approach seemed ideal for this study.

The persistence analysis methodology was designed to be consistent with the approach taken by SCE to estimate first-year savings. The approach involved the following steps:

- First, RER implemented some minor changes in the specific modeling methodology used in the first-year impact study. These changes involved the adjustment of engineering estimates of usage and savings for variations in weather conditions, expansions of the model to include additional variables designed to control for other changes at the sites in question, and a different specification for the deadband around the audit date for program participants.
- Second, the data used to estimate the model were expanded to cover a second post-program year. This entailed the collection of additional billing data and weather data, however, it did not require the collection of any updated survey data.
- Third, the model was estimated using the expanded sample period. Savings variables were interacted with three measures of time—a linear time term, a logarithmic time term, and a binary variable representing the second year of the post-program year—in order to allow changes in savings over time.

- Finally, the expanded model was used to simulate the end-use impacts of the program for the first and second post-program periods.

First-Year Impact Model

The realization rate model used in the first-year study can be specified as:

$$(5)\quad KWH_{it} = f\begin{pmatrix} CONSPE_{it}, CONSNPE_{it}, HTESV_{it}, ACESV\_SP_{it}, \\ ACESV\_UNSP_{it}, WHESV_{it}, REFESV\_SP_{it}, \\ REFESV\_UNSP_{it}, FRZESV_{it}, SPPLESV\_UNSP_{it}, \\ LDRYESV_{it}, PART_i, TREND_{it}, \varepsilon_i \end{pmatrix}$$

where:

KWH_{it}	=	electricity usage in month t for household i
$CONSPE_{it}$	=	a pre-audit engineering estimate of a participant's whole-house consumption in month t
$CONSNPE_{it}$	=	an engineering estimate of a nonparticipant's whole-house consumption in month t
$HTESV_{it}$	=	an engineering estimate of savings from recommended heating measures for participant i in month t
$ACESV\_SP_{it}$	=	an engineering estimate of savings from recommended cooling measures for participant i in month t, where the participant specified that the measure was implemented
$ACESV\_UNSP_{it}$	=	an engineering estimate of savings from recommended cooling measures for participant i in month t, where the participant did not specify whether or not the measure was implemented
$WHESV_{it}$	=	an engineering estimate of savings from recommended water heating measures for participant i in month t
$REFESV\_SP_{it}$	=	an engineering estimate of savings from recommended refrigeration measures for participant i in month t, where the participant specified that the measure was implemented
$REFESV\_UNSP_{it}$	=	an engineering estimate of savings from recommended refrigeration measures for participant i in month t, where the participant did not specify whether or not the measure was implemented
$FRZESV_{it}$	=	an engineering estimate of savings from recommended freezer measures for participant i in month t

$SPPLESV\_UNSP_{it}$	=	an engineering estimate of savings from recommended spa/pool measures for participant *i* in month *t*, where the participant did not specify whether or not the measure was implemented
$LDRYESV_{it}$	=	an engineering estimate of savings from recommended washer/dryer measures for participant *i* in month *t*
$PART_i$	=	a binary indicator of participation in the program
$TREND_{it}$	=	a trend variable
ε_{it}	=	a random error term

In the context of this model, estimated program savings can be derived by end use. For instance, the space heating savings estimate for participant *i* in month *t* is derived as:

$$(6)\quad Space\ Heating\ Savings_{it} = \frac{\partial KWH_{it}}{\partial HEATE_{it}} HTESV_{it}$$

These estimates are aggregated across months and participants in order to develop annual estimates of end-use program savings.

Second-Year Impact Model

In order to investigate the persistence of second-year savings for 1993 EUPP participants, the model used in the earlier study was specified to include time terms for each of the savings variables. Specifically,

$$(7)\quad KWH_{it} = f\begin{pmatrix} CONSPE_{it}, CONSNPE_{it}, HTESV_{it}, ACESV\_SP_{it}, ACESV\_UNSP_{it}, \\ WHESV_{it}, REFESV\_SP_{it}, REFESV\_UNSP_{it}, FRZESV_{it}, \\ SPPLESV\_UNSP_{it}, LDRYESV_{it}, HTESV_{it} \times TIME_t, \\ ACESV\_SP_i \times TIME_t, ACESV\_UNSP_{it} \times TIME_t, \\ WHESV_{it} \times TIME_t, REFESV\_S_{it} \times TIME_t, \\ REFESV\_UNSP_{it} \times TIME_t, FRZESV_{it} \times TIME_t, \\ SPPLESV\_UNSP_{it} \times TIME_t, SPPLESV\_UNSP_{it} \times TIME_t, \\ LDRYESV_{it} \times TIME_t, PART_i, TIME_{it}, \varepsilon_i \end{pmatrix}$$

where the following definitions apply:

$TIME_{it}$	=	time trend equal to 0 up until 15 months after the audit—at that time it increments by 1 for each month

Model Estimation

The First-Year and Multi-Year Models were estimated using subsets of the impact database reflecting the time period covered by the models. The estimation of each model is discussed below.

First-Year Model

Table 3-4 presents the model coefficient estimates and goodness-of-fit statistic (R-square) for the First-Year and First-Year *autocorrelation corrected* Models. Over the course of estimating this model, a number of modeling issues were identified. This required appropriate changes to the model specification and/or the estimation technique. A discussion of the major issues follow.

Implementing A Deadband. The preliminary specification of the First-Year Model does not fully recognize the dynamics of audit impacts. Participant implementations are typically distributed over time. Some practices are implemented soon after the audit, but others (especially those requiring an initial investment) are implemented only after some time has elapsed. although some information on the timing of adoptions was available from the earlier follow-up survey, the timing of most actions was unknown. Assuming that these "unspecified" actions took place at the time of the audit—or shortly after the audit, for that matter—can bias estimated impacts downward. This problem was addressed to some extent by defining a three-month "deadband" immediately after each participant's audit. This practice essentially excludes those months over which the impact of the audit may not be complete.

Definition of First-Year Period. The first-year period is defined to be 15 months after the audit date. This is consistent with the 12 months following the end of the imposed 3-month deadband after the audit. Therefore, the database used to estimate the First-Year model includes data up to 15 months after the date of the audit for participants and up to the end of 1994 for nonparticipants.

Weather Adjustments. Considerable time was spent reviewing the weather adjustments used in the earlier study. As is explained in Section 3.2, the weather adjustment factors were re-specified and applied to weather sensitive end-use estimates of usage and savings.

Changes in Model Specification. The model specification was changed in two areas. First, three variables designed to explain changes in energy use due to the addition of square footage at the home were added:

$ADDSF\_A_{it}$	=	a binary variable equal to 1 after January 1 1993 if square feet were added to the home, 0 otherwise.

$ADDSF\_AC_{it}$ = $ADDSF\_A_{it} \times CDD_i \times AC_i$, where AC_i is a binary variable indicating the presence of air conditioning.

$ADDSF\_AH_{it}$ = $ADDSF\_A_{it} \times HDD_i \times SH_i$, where SH_i is a binary variable indicating the presence of electric space heating.

Second, the engineering estimate of household consumption ($CONSNPE_{it}$) proved to be unreliable and relatively uncorrelated with actual consumption. As an alternative, the 12-month lag of consumption ($LAGECON_{it}$) was used as a proxy for expected household consumption for nonparticipants. Further, to account for nonparticipant households with weather-sensitive end uses, the following variables were added to adjust for weather impacts on household usage:

$NPACSF_{it}$ = $\Delta CDD_i \times AC_i$ where AC_i is a binary variable indicating the presence of air conditioning, and ΔCDD_i is the 12-month change in cooling degree days, 0 for nonparticipants households

$NPSHSF_{it}$ = $\Delta HDD_i \times SH_i$ where SH_i is a binary variable indicating the presence of electric space heating, and ΔHDD_i is the 12-month change in heating degree days, 0 for nonparticipants households

Correction for Autocorrelation. Autocorrelation, which is the correlation of the error term over time for individual sites, is typical in analyses of energy usage over time. This problem was mitigated with generalized least squares, a standard remedy. Table 3-4 presents model coefficients and goodness-of-fit statistics for the First-Year Model corrected for autocorrelation.

Table 3-4: First-Year Impact Model

Explanatory Variable	First-Year Model	First-Year Model Corrected for Autocorrelation
Intercept	99.6510 (57.82)	82.5449 (59.42)
$CONSPE\_1_{it}$	0.9459 (380.08)	0.5499 (251.92)
$HTESV_{it}$	-0.1903 (-5.55)	-0.0876 (-2.05)
$ACESV\_S_{it}$	-0.7072 (-7.56)	−0.2753 (-2.36)
$ACESV\_UNS_{it}$	-0.1103 (-4.70)	−0.1460 (-4.76)
$WHESV_{it}$	-0.1802 (-4.35)	-0.5119 (-7.80)
$REFESV\_S_{it}$	-0.9468 (-11.48)	−1.0969 (-9.01)
$REFESV\_UNS_{it}$	-0.1243 (-5.34)	−0.3876 (-10.43)
$FRZRESV_{it}$	-0.2797 (-4.33)	-0.7496 (-7.24)
$SPPLESV_{it}$	-1.4428 (-3.04)	-1.4090 (-1.85)
$LDRYESV_{it}$	-0.1337 (-0.67)	-0.8192 (-2.57)
$LAGECON_{it}$	.8601 (401.47)	0.7513 (258.81)
$NPACSF_{it}$	0.9210 (72.89)	0.8420 (73.98)
$NPSHSF_{it}$	0.08321 (4.16)	0.07098 (4.04)
$ADDSF\_A_{it}$	0.08321 (14.63)	0.09016 (10.39)
$ADDSF\_AC_{t}$	0.0001570 (1.88)	0.000360 (3.62)
$PART_{it}$	-74.75 (-16.06)	-149.6 (-48.25)
$TREND_{it}$	0.003704 (27.43)	0.007336 (41.94)
Adjusted R-Square	***0.83***	***0.69***

Multi-Year Model

The specification of the Multi-Year Model is designed to analyze the persistence of savings. This is accomplished by specifying time trend terms interacted with engineering estimates of first-year savings. This model is estimated with pre-audit data, as well as data covering the 24 months following the audit. Two model versions were estimated using this approach. These include:

- ***Version A: Full Savings Model.*** In this model, savings terms are disaggregated by end use, specified and unspecified. Time terms are interacted with each savings term.
- ***Version B: Collapsed Savings Model.*** This model collapses savings for specified and unspecified measures and practices by end use. The savings terms are interacted with time trend.

Model estimates for these models are presented in Table 3-5. Issues common to all models are discussed below. In addition, issues pertaining to specific models are explained.

Addition of Time Trends. Three different time trend specifications were tested in the models. These included: (1) a straight time trend that increments by 1 for each month beyond the *first year* after the audit date, (2) a log of the straight time trend, and (3) the inverse of the straight time trend. The straight time trend was ultimately used as it led to the most significant and plausible results.

Collapsing Air Conditioning and Refrigeration Savings. Specified and unspecified refrigeration and air conditioning savings were estimated separately in the First-Year Model. In the Multi-Year Model, the specified and unspecified estimates of savings were used to specify a single end-use savings term. The specification was based on the relevant parameter estimates from the First-Year Model. In particular,

$$(8)\quad ACESV\_COMB_{it} = ACESV\_SP_{it} + \frac{0.1103}{0.7072} \times ACESV\_UNSP_{it}$$

$$(9)\quad REFESV\_COMB_{it} = REFESV\_SP_{it} + \frac{0.1243}{0.9468} \times REFESV\_UNSP_{it}$$

This approach assumes the same *relative* savings across specified and unspecified measures and practices for these end uses across time.

Total Savings. The total household savings variable (TOT_SAV_{it}) was constructed using parameter estimates from the First-Year Model. In particular, end-use savings estimates were multiplied by the parameter estimate (realization rate) from the First-Year Model and then summed across end uses. This assumes that the *relative* savings remain constant through time. Since this assumption is arguable, this variable was used in only one version of the Multi-Year Model.

Correction for Autocorrelation. The Multi-Year Model was also corrected for autocorrelation. Table 3-6 presents the two versions of the model corrected for autocorrelation.

Version A. Model Version A includes savings for all end uses and a time trend interacted with each savings term. The insignificance of the time trend parameter estimate for spas and pools suggest full persistence of savings for this end use. Further, in the case of refrigeration, laundry, freezers, and water heating, savings appear to increase over time. This result may be due to the timing of measure adoption. In particular, some of the unspecified measures may have been adopted late in the first year. Therefore, savings appear to be larger in the second year and are accounted for by the time-trend variable.

Version B. This model is similar to model Version A; however, the time trend is interacted only with end-use saving for air conditioning and space heating. The time trends on the other non-weather sensitive end uses were dropped due to insignificance or incorrect signs. The autocorrelation-corrected form of the model is used to develop estimates of savings reported in the following section.

Table 3-5: Multi-Year Impact Models

Variable	Version A	Version B
Intercept	87.5898 (62.03)	87.6360 (62.07)
CONSPE_it	0.9436 (430.54)	0.9437 (430.66)
$HTESV_{it}$	-0.1604 (-5.56)	-0.1507 (-5.24)
$HTESVT_{it}$	0.006079 (1.53)	0.004526 (1.15)
$ACESV\_COMB_{it}$	-0.4306 (6.14)	-0.4173 (-5.95)
$ACESV\_COMBT_{it}$	0.08064 (10.09)	0.07748 (9.74)
$WHESV_{it}$	-0.03535 (-0.96)	-0.1072 (-3.82)
$WHESV_{it} \times TIME_t$	-0.01080 (-2.96)	–
$REFESV\_COMB_{it}$	-0.7078 (-11.52)	-0.8102 (-18.81)
$REFESV\_COMB_{it} \times TIME_t$	-0.01368 (-2.28)	–
$FRZRESV_{it}$	-0.1023 (-1.79)	-0.08678 (-2.02)
$FRZRESV_i \times TIME_t$	0.001939 (0.33)	–
$SPPLESV_{it}$	-0.3418 (-0.77)	-0.06595 (-0.18)
$SPPLESV_{it} \times TIME_t$	0.06296 (1.11)	–
$LDRYESV_{it}$	0.4170 (2.36)	0.06652 (0.52)
$LDRYESV_i \times TIME_t$	-0.04654 (-2.78)	–
$LAGECON_{it}$	0.8668 (504.19)	0.8668 (504.26)
$NPACSF_{it}$	0.000867 (86.02)	0.000868 (86.06)
$NPSHSF_{it}$	0.000220 (16.51)	0.000220 (16.51)
$ADDSF\_A_{it}$	0.07933 (18.48)	0.07926 (18.47)
$ADDSF\_Ac_t$	0.000406 (6.45)	0.000405 (6.44)
$PART_{it}$	-57.1382 (-33.44)	-57.1150 (-33.42)
$TREND_{it}$	0.001562 (22.92)	0.001555 (22.85)
Adjusted R-Square	0.81	0.81

Table 3-6: Multi-Year Impact Models: Corrected for Autocorrelation

Variable	Version A	Version B
Intercept	76.9880 (72.73)	77.02755 (72.78)
$CONSPE\_it$	0.8907 (283.73)	0.8908 (283.72)
$HTESV_{it}$	-0.3779 (10.90)	-0.3695 (-10.68)
$HTESV_{it} \times TIME_t$	0.001685 (0.35)	0.000443 (0.09)
$ACESV\_COMB_{it}$	-0.8060 (-9.05)	-0.7955 (-8.92)
$ACESV\_COMB_{it} \times TIME_t$	0.08399 (8.85)	0.08128 (8.59)
$WHESV_{it}$	-0.02966 (-0.49)	-0.1422 (-3.16)
$WHESV_i \times TIME_t$	-0.01555 (-2.73)	–
$REFESV\_COMB_{it}$	-0.8293 (-8.54)	-0.9423 (-13.91)
$REFESV\_COMB_{it} \times TIME_t$	-0.01437 (-1.58)	–
$FRZRESV_{it}$	-0.1326 (-1.38)	-0.1407 (-2.02)
$FRZRESV_i \times TIME_t$	-0.001934 (-0.21)	–
$SPPLESV_{it}$	-0.1285 (-0.17)	-0.03587 (-0.06)
$SPPLESV_{it} \times TIME_t$	-0.01487 (-0.17)	–
$LDRYESV_{it}$	0.3973 (1.34)	-0.08742 (-0.42)
$LDRYESV_i \times TIME_t$	-0.05809 (-2.22)	–
$LAGECON_{it}$	0.7313 (316.61)	0.7313 (316.64)
$NPACSF_{it}$	0.000757 (84.95)	0.000757 (84.98)
$NPSHSF_{it}$	0.000176 (15.95)	0.000176 (15.95)
$ADDSF\_A_{it}$	0.08886 (13.07)	0.08877 (13.06)
$ADDSF\_AC_t$	0.000553 (7.54)	0.000552 (7.53)
$PART_{it}$	-108.3458 (-43.08)	-108.3344 (-43.07)
$TREND_{it}$	0.004075 (39.66)	0.004065 (39.59)
Adjusted R-Square	0.66	0.66

4

Results

4.1 Introduction

This section presents the results from the second-year impact analysis of the Energy-Use Profiles Program (EUPP). First-year impacts were also estimated in the course of developing second-year impacts. The results of the analysis indicate that annual first-year savings are 124 kWh per participant. This drops by 7% to 115 kWh in the second year due to the lack of persistence of space conditioning related practices.

The following sections present a summary of recommended measures and practices, first-year savings, a comparison to the first-year impacts estimated in the SCE 1993 Impact Evaluation of the EUPP (Samiullah, 1995), and second-year savings results.

4.2 Recommended Measures

The focus of this analysis is to evaluate the persistence of savings by end use using a realization rate modeling approach. Key elements in this analysis are adoption of recommended measures and practices, timing of adoption, and the estimated energy savings due to implementation of the recommendation(s).

Table 4-1 presents a summary of the adoptions of recommended conservation measures and practices the average engineering estimates of annual savings. As shown in Table 4-1, roughly 59% of the expected savings is attributable to refrigeration measures, air conditioning, space heating, and freezers account for 11% each, and water heating accounts for 7%.

The mix between measures and practices suggests that approximately 85% of all savings are attributable to measures. The practices are mainly thermostat changes to space conditioning and lowering of water heater delivery temperatures.

Table 4-1: Engineering Estimates of Savings and Percent of Participants Who Received Recommendations

Measure/Practice	Average Engineering Estimate of Savings (kWh)	Percent of Participants who Received Recommen-dation	Expected per Participant Savings from Recommen-dation	Percent of Annual Expected Savings
Air Conditioning		***9.36***		
upgrade attic insulation	469	.47	2.20	0.45
install whole-house fan	534	3.14	16.77	3.40
raise thermostat	451	5.32	23.99	4.87
replace central air conditioner	2,472	.30	7.42	1.51
replace room air conditioner	357	.62	2.21	0.45
Space Heating		***7.85***		
upgrade attic insulation	207	.39	0.81	0.16
lower thermostat when not at home	707	6.36	44.97	9.13
lower thermostat at night	339	1.69	5.73	1.16
install weather stripping	131	.45	0.59	0.12
Water Heating		***6.37***		
lower water heating setting	559	2.93	16.38	3.33
install low flow showerheads and faucet aerators	427	2.70	11.53	2.34
install water heater tank wrap	160	2.42	3.87	0.79
replace electric water heater	152	.05	0.08	0.02
wash in cold water	342	.93	3.18	0.65
Refrigeration		***31.72***		
replace primary refrigerator	727	21.50	156.31	31.73
unplug second refrigerator when not in use	995	13.17	131.04	26.60
unplug third refrigerator when not in use	863	.47	4.06	0.82
Freezers		***6.19***		
replace frost free freezer	752	1.76	13.24	2.69
replace	565	4.27	24.13	4.90
unplug second freezer when not in use	764	2.24	17.11	3.47
Spa/Pools		***0.09***		
install spa cover	463	.09	0.42	0.08
Laundry		***2.38***		
install outdoor clothes line	276	2.38	6.57	1.33

4.3 First-Year Savings

The final model used to estimate second-year savings (Model Version B) may also be simulated to estimate first-year realized savings. Table 4-2 presents results of first-year savings using actual weather conditions. Included in the table are realization rates by end use, engineering estimate of savings, proportion of participants adopting the measure, and monthly and annual savings. Note that realization rates on unspecified savings embody implementation rates as well as conventionally defined realization rates. First-year savings are estimated to be 123 kWh under actual weather conditions.

Table 4-3 presents first-year savings by end use under normal weather conditions. Per participant savings under normal and actual weather conditions differ by only about 1%. This is understandable as weather conditions for the analysis period were very similar to normal weather conditions, and weather sensitive end-use-related adoptions accounted for about 24% of savings. Breakout of savings by end use is illustrated in Figure 4-1.

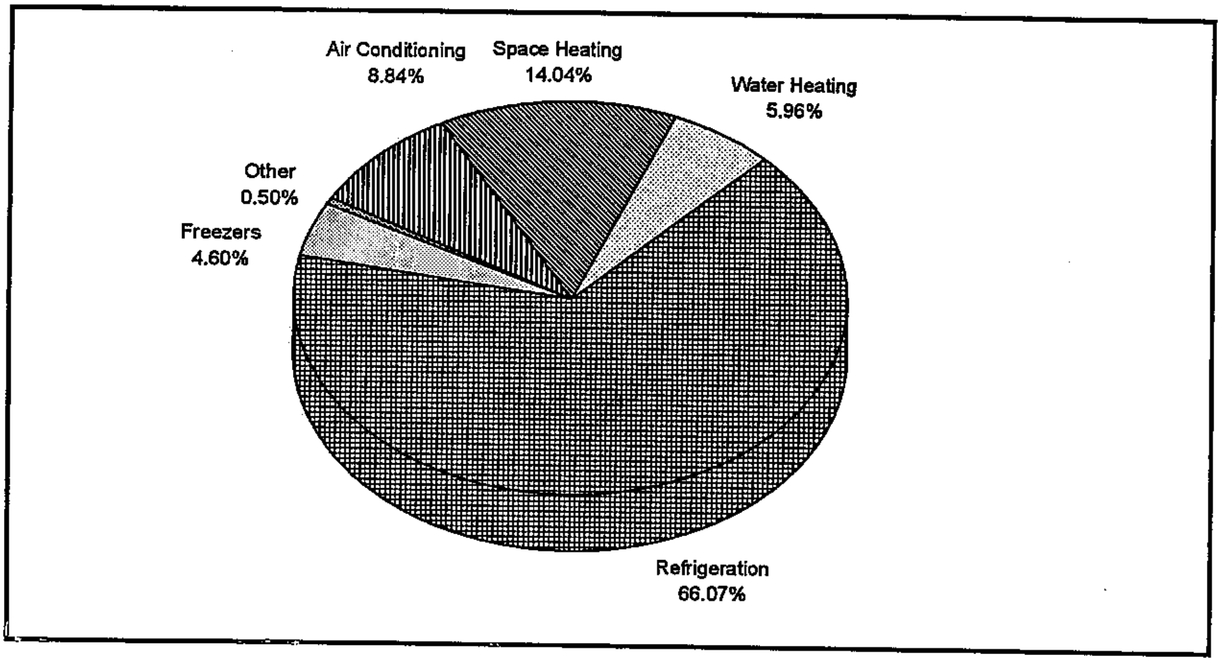
Table 4-2: First-Year Savings by End Use - Actual Weather

End Use	Realization Rate	Engineering Estimate	Proportion Adopting Measure	Savings (kWh)
Air Conditioning				
Unspecified	0.0879	47	6.27	0.259
Specified	0.5625	37	2.78	0.584
Space Heating	0.3695	57	6.92	1.448
Water Heating	0.1422	46	9.57	0.613
Refrigeration				
Unspecified	0.1171	74	27.70	2.405
Specified	0.8922	74	6.70	4.391
Freezers	0.1407	53	6.38	0.473
Spa/Pool	0.0359	39	0.10	0.001
Laundry	0.0874	23	2.53	0.050
			Monthly Savings	**10.22**
			Annual Savings	**122.67**

Table 4-3: First-Year Savings by End Use - Normal Weather

End Use	Realization Rate	Engineering Estimate	Proportion Adopting Measure	Savings (kWH)
Air Conditioning				
Unspecified	0.0879	51	6.27	0.279
Specified	0.5625	40	2.78	0.630
Space Heating	0.3695	56	6.92	1.444
Water Heating	0.1422	46	9.57	0.613
Refrigeration				
Unspecified	0.1171	74	27.70	2.405
Specified	0.8922	74	6.70	4.391
Freezers	0.1407	53	6.38	0.473
Spa/Pool	0.0359	39	0.10	0.001
Laundry	0.0874	23	2.53	0.050
			Monthly Savings	**10.29**
			Annual Savings	**123.43**

Figure 4-1 : Annual First-Year Savings by End Use - Normal Weather



4.4 Comparison of First-Year Savings with Previous Analysis

A comparison of first-year savings in this study with those estimated in the SCE-sponsored study (Samiullah, 1995) are presented in Table 4-4. As shown, estimated first-year savings from this study are roughly 56% of the estimates made in the previous study.

The differences in estimated savings may be due to the expanded sample size and/or changes in the specification of weather adjustments to the engineering estimates of usage and savings. In particular, the previous study did not have access to a full year of post-participation data for some participants, used more than a year's worth of data for other participants, and used nonparticipant data only up through September of 1994. This study considered 12 months of *post-deadband* data to constitute the first year, and included nonparticipant data through the end of 1994.

Table 4-4: Comparison of First-Year Annualized Savings - Actual Weather

End Use	1993 Study	1996 RER
Air Conditioning	0.81	0.84
Space Heating	1.64	1.45
Water Heating	2.33	0.61
Refrigeration	10.81	6.80
Freezers	2.10	0.47
Spa/Pool		0.001
Laundry	0.55	0.05
Monthly Savings	18.24	10.22
Annual Savings	219.09	122.67

4.5 Second-Year Savings

Model Version B, corrected for autocorrelation, was used to estimate second-year savings. Table 4-5 presents first- and second-year net savings by end use under actual and normal weather conditions. Second-year savings are estimated to be 115 kWh per participant, annually under normal weather conditions. This is a reduction of roughly 7% from first-year savings.

As indicated in Table 4-5, just over 77% of annual first-year savings is attributable to the adoption of refrigeration measures and practices. Due to the lack of persistence of the weather sensitive end-use-related measures and practices, this climbs to roughly 82% in the second year.

Savings from measures and practices associated with all non-weather sensitive end uses show persistence of savings over the second year of the program. This is understandable, as the majority of adopted program recommendations are measures compared to practices. For example, the majority of refrigeration and freezer related adoptions are replacement of primary units.

The lack of persistence from space heating and air conditioning adoptions may be attributable to the mix of measures and practices. In particular, over 85% of space heating and just under 50% of air conditioning related adoptions were practices associated with changes in thermostat settings. This lack of persistence is consistent with the typical unreliability of self-reported conservation actions dealing with thermostat settings.

Table 4-5: First- and Second-Year Savings by End Use

	Actual Weather		*Normal Weather*	
End Use	**First-Year Savings**	**Second-Year Savings**	**First-Year Savings**	**Second-Year Savings**
Air Conditioning	0.842	0.204	0.909	0.217
Space Heating	1.448	1.440	1.444	1.392
Water Heating	0.613	0.613	0.613	0.613
Refrigeration	6.796	6.796	6.796	6.796
Freezers	0.473	0.473	0.473	0.473
Spa/Pool	0.001	0.001	0.001	0.001
Laundry	0.050	0.050	0.050	0.050
Monthly Savings	10.22	9.58	10.29	9.54
Annual Savings	122.67	114.91	123.43	114.49

Figure 4-2: First-Year Versus Second-Year Savings