Aspen Systems Corporation

May 11, 1994

Mr. Peter Miller
Natural Resources Defense Council
71 Stevenson Street, Suite 1825
San Francisco, CA 94105

SUBJECT: Southern California Edison Purchase Order No. K2024903, Draft Report, Summary of California DSM Evaluation Studies (Aspen Project Number 7900.000)

Dear Peter:

Enclosed for your review and comment are ten copies of our draft report summarizing the California Utility DSM Evaluation Studies. A separately bound appendix which contains the abstracts of all of the studies will be forwarded shortly under separate cover.

Marilyn Brown and I look forward to receiving your and the other committee members comments on the draft report. While we would like to receive all of the comments, to facilitate the comment process, it would be very useful if you could synthesize the comments received so as to provide one non-conflicting set of comments for us to use. This will allow us to efficiently incorporate the committee's comments on the draft report and produce a final summary report.

As you will see when reading the report, several areas for further research or analysis on the evaluation findings are apparent. However, due to the tight budget for this project, we have been unable to pursue these additional areas. Should the committee have an interest, and if additional funding could be made available, Marilyn and I would be very interested in further analysis of the important information contained in these studies.

As you know, this effort has presented us with many challenges. The methods and results vary widely across the four utilities and the over 50 studies which were reviewed. We hope that this effort provides the committee with useful summary information on the contents of the evaluation studies.

We look forward to receiving your comments and delivering the final report. In the interim, should you have any questions, please feel free to call me at (615) 482-2721.

Sincerely,

Philip E. Mihlmester
Vice President
Energy and Technology Services

cc: Southern California Edison Company
Attention: Marian Brown
Re: SCE Purchase Order No. K2024903
300 N. Lone Hill Avenue
San Dimas, CA 91773

Draft Report

Summary of California DSM Impact Evaluation Studies

SCE Purchase Order K2024903

(Aspen Project No. 7900-000)

Prepared for:

California DSM Measurement Advisory Committee (CADMAC)
c/o Peter Miller
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San Francisco, CA 94105

Prepared by:

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May 11, 1994

EXECUTIVE SUMMARY

Over the past two years, four of the largest California utilities have initiated formal evaluation studies designed to measure the energy and demand impacts of their DSM programs. The four utilities include: Pacific Gas and Electric Company, San Diego Gas and Electric Company, Southern California Edison, and Southern California Gas Company. These utilities, along with nine additional organizations comprise the California Demand Side Management Measurement Advisory Committee (CADMAC), which was established by the California Public Utilities Commission to oversee the measurement and evaluation activities of these utilities.

Since 1992, the above four utilities have submitted over 50 studies which attempt to evaluate their residential, commercial, industrial, and agricultural DSM programs. The objective of this report is to summarize the results of these evaluation studies in an accessible and consistent format.

As background, information was collected and summarized on the magnitude of the DSM programs sponsored by the four utilities. Between 1990 and 1992, the four utilities spent $772 million on energy efficiency conservation expenditures. Almost half of this total ($358 million) was expended by Pacific Gas and Electric, the largest of the four utilities, while somewhat less than $70 million was spent by San Diego Gas and Electric, the smallest. DSM expenditures were divided across several program types including: retrofit energy efficiency incentives ($178 million), direct assistance ($226 million), new construction programs ($77 million), and energy management services ($157 million) over this period. These programs served more than 900,000 participants annually between 1990 and 1992.

The report summarizes ex-post energy savings on a programmatic and measure level. Several important caveats must be noted however, with respect to savings reported. These relate to variations in the format of the reported savings across the four utilities and across the evaluation studies. Different time periods for evaluation, savings units, and methodological approaches were employed in the estimation of savings which make it difficult to establish consistent savings estimates and aggregate them across the four utilities.

For residential programs, Southern California Edison's Customer Assistance Program for 1990-1991, which included weatherization, hardware, and relamping incentives, reported the largest programmatic total of 24,381 megawatt hours per year. This was followed by PG&E's Residential Compact Fluorescent Lighting Program, which reported electrical energy savings of 13,807 megawatt hours per year. Southern California Gas Company's Residential EMS Program reported gas savings of 1,693,000 therms per years.

In the nonresidential sectors, PG&E's Commercial, Industrial, and Agricultural Retrofit Rebate Program reported over 663,000 megawatt hours of savings for the 1991-1992 period. This same program accounted for 110,531 kilowatts of demand savings.

Several utilities, including Southern California Gas, Southern California Edison, and San Diego Gas and Electric, reported commercial, industrial, and agricultural energy savings on a per measure or measure class or average building basis. In terms of electrical energy savings, HVAC and lighting measures, as a class, reported substantial savings, as did high efficiency commercial boilers on the gas side. The evaluation studies often reflected wide variation in savings estimates on a per measure or per measure category basis. For example, *ex-post* savings reported across the studies varied between 33 kilowatt hours and 128 kilowatt hours per compact fluorescent bulb per year.

This report also summarizes realization rates from the evaluation studies reviewed. Realization rates are defined as ex-post savings estimates divided by ex-ante savings estimates. Realization rates are summarized for 158 programs and program segments. The Distribution of realization rates by utility is shown in Figure SUM.1. The median realization rate for all programs and program segments is 0.86. This means that, on average, 86 percent of the projected savings from these programs were realized (on an unweighted basis). The realization rates ranged widely from a low of 0.03 to a high of 14.54. The distribution of realization rates is highly skewed with 62% falling within a narrow range from 0.5 to 1.25, but with several surpassing 4.0. Southern California Gas and San Diego Gas and Electric had the lowest median values for their realization rates (0.66 and 0.68 respectively). Southern California Edison had the highest median value, 0.87, and PG&E's median realization rate is almost as high at 0.82.

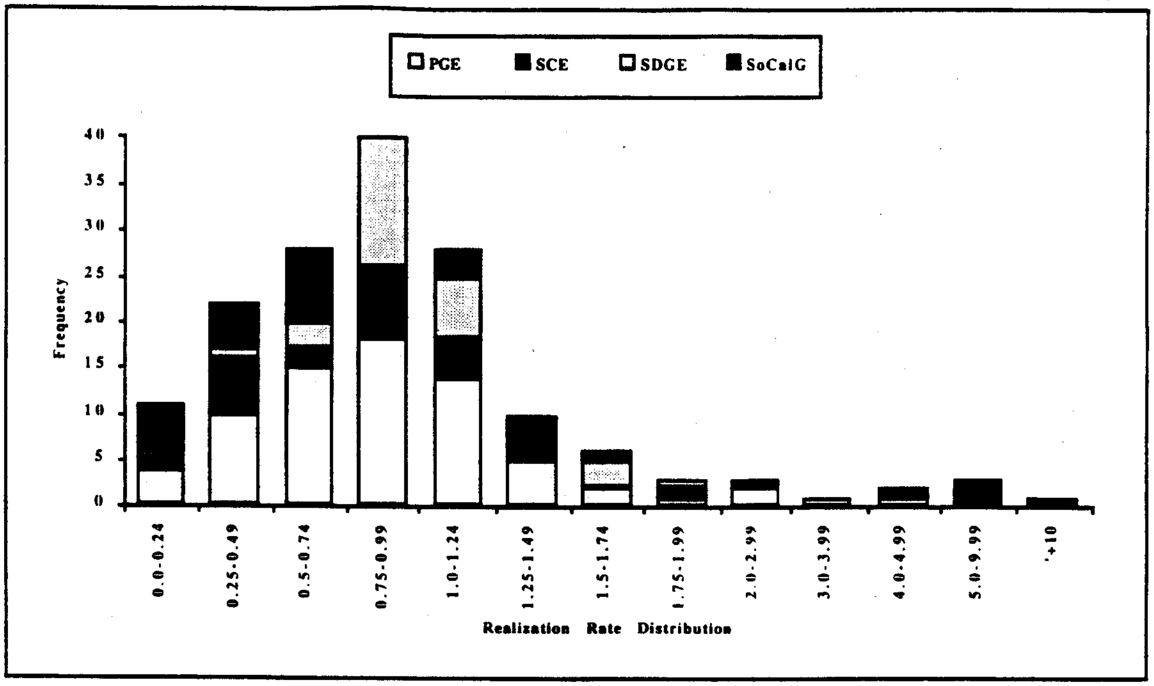


Figure SUM.1 Distribution of Realization Rates (N=158)

By comparing the realization rates for each of three DSM measures (compact fluorescent lamps, low-flow showerheads, and refrigerator replacements), it is possible to suggest features of the DSM programs, the *ex-ante* estimates of savings, and the evaluation methods that may cause realization rates to vary. In the residential sector, high realization rates are associated with calibrated engineering models, relatively low *ex-ante* estimates of savings, and evaluations that fail to discount savings for free riders, rebound effects, and imperfect measure retention.

As part of this summary, reviews of the studies by the California Public Utilities Commission (CPUC) Division of Ratepayer Advocacy (DRA) and the California Energy Commission (CEC) were summarized, as were the rebuttals of two utilities. The review comments encompassed several areas of concern. These included:

- Methods (including the use of comparison groups) to isolate DSM program effects from underlying market conditions,
- Sample design issues associated with the evaluations,
- Error estimates and confidence levels associated with the reported savings,
- Specific methodological concerns regarding the use of two evaluations methods in particular: conditional demand analysis and engineering simulation modeling,

- Methodological and data issues associated with net to gross analysis,
- Lack of long run weather normalization and reporting of peak demand impacts especially in the residential sector, and
- Triangulation decision rules associated with determining the best estimate of savings when different methods are employed.

Appendix A to this report contains a bibliography of the evaluation studies summarized, while Appendix B presents a summary of the evaluation of the methodologies employed. Appendix C, which is separately bound, contains abstracts of the evaluation studies.

It is recommended that future efforts of this type would benefit substantially from common formats to be used by all of the utilities in reporting energy savings and evaluation results. This would allow consistent comparisons of savings and permit appropriate aggregations across utilities.

CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND

Since the late 1980's, California utilities have initiated various demand side management (DSM) programs designed to reduce the demand for energy by utilities' customers. Over the past two years, four of the largest California utilities have initiated formal evaluation studies designed to measure the energy and demand impacts of their DSM programs. The four utilities include:

- Pacific Gas and Electric Company,
- San Diego Gas and Electric Company,
- Southern California Edison, and
- Southern California Gas Company.

These utilities, along with nine additional organizations, comprise the California Demand Side Management Measurement Advisory Committee (CADMAC), which was established by the California Public Utilities Commission (CPUC) to oversee the measurement and evaluation activities of these utilities.

Over the past several years, these four utilities have produced over 50 studies designed to retrospectively evaluate the energy (gas and electric) and electrical demand impacts achieved by the cumulative investment of nearly one billion dollars by the four utilities in demand side management programs. These impact studies are listed by study ID number in Table 1.1.

Table 1.1: LOAD IMPACT STUDIES USED OR EXPECTED TO BE USED TO REVISE EX-ANTE ESTIMATES OF LOAD IMPACTS PER UNIT (Identified by Study ID Number--see Appendix A for study titles)

PROGRAM(S)	PG&E	EDISON	SOCALGAS	SDG&E
Residential Retrofit Incentives	RWRI: 12(9/93); 13 (9/93) RAEI: 14 (9/93); 15 (6/93).	RWRI: (not applic.) RAEI: 64 (6/93); 65 (8/93); 67 (7/93); 69 (11/93).	RWRI & RAEI: 129	RWRI: (not applic.) RAEI: 144; 156; 155 (6/93)
Non-Residential Retrofit Incentives	C/I/A: 31; 32; 37; 43 (9/93)	Comm: 87 (7/93); 88 (9/93); 92 (9/93); Indust: 95 (10/93) Agric: 94 (10/93)	Comm: 137 (11/93) Indust: 139 (11/93)	Comm: 165; 174 (6/93); 185 (11/93) (Ind: Not applic.)
Residential Direct Assist.	22 (12/93); 24 (12/93)	68 (9/93)	130 (7/93)	158 (11/93)
Residential New Construction	20 (12/93)	76 (9/93) 77 (11/93)	132 (10/93)	(no completed studies required until 1995)
Nonresidential New Construction	44 (10/93)	101 (11/93)	140 (11/93)	(no completed studies required until 1995)
Residential EM Services	26 (12/93)	66 (6/93)	195 (9/93)	157 (9/93)
Nonresidential EM Services	48 (12/93)	(included in 87, 92, 94, 95)	(included in 137 and 139)	(no additional studies until 1994)
COMPLETED STUDIES USED FOR PROG. YEAR 1993 OR 1992 REVISIONS	RAEI: 5, 6, 7, 8, 39. NREEI: 31, 32, 37, 179. NRNC: 36.	GENERAL (engineering-based upgrades) 86; 55. LOAD SHAPE: 60, 82, 83	None	RAEI: 149, 150, 152. CEEI: 165 NREMS: 1621

1.2 OBJECTIVES OF THIS REPORT

The evaluation studies produced by the four utilities contain much detailed information related to the measurement of energy and demand impacts of the utilities' DSM programs. Many of the studies are multi-volume and examine the impact issues from several methodological perspectives.

The objective of this report is to summarize the results of the individual evaluation studies listed in Table 1.1 in an accessible and readable format such that CPUC commissioners, their aides, and utility management can have access to the essential facts and figures which describe the impacts of these four utilities' programs.

In defining their programs, and in annual reporting of program status, the individual utilities formulated preliminary estimates of program impacts. These impact estimates are known as *ex-ante* impact estimates. In most cases, they are based on engineering estimates. The formal evaluation studies, summarized in this report, estimate impacts based on retrospective measurement and/or estimates of key parameters. Thus the impact evaluation studies summarized in this report produced *ex-post* impact estimates. A key objective of this report is to compare the *ex-ante* and *ex-post* impact estimates of the four utilities' DSM programs. This was accomplished by formulating "realization rates", which are the ratio of the *ex-post* to the *ex-ante* estimates.

Finally, the impact evaluations have been subjected to independent review by the California Public Utilities Commission Division of Ratepayer Advocacy (DRA) and the California Energy Commission (CEC). To the extent such comments were made available, this report summarizes the review comments received, as well as utility responses to these comments.

1.3 ORGANIZATION OF REPORT

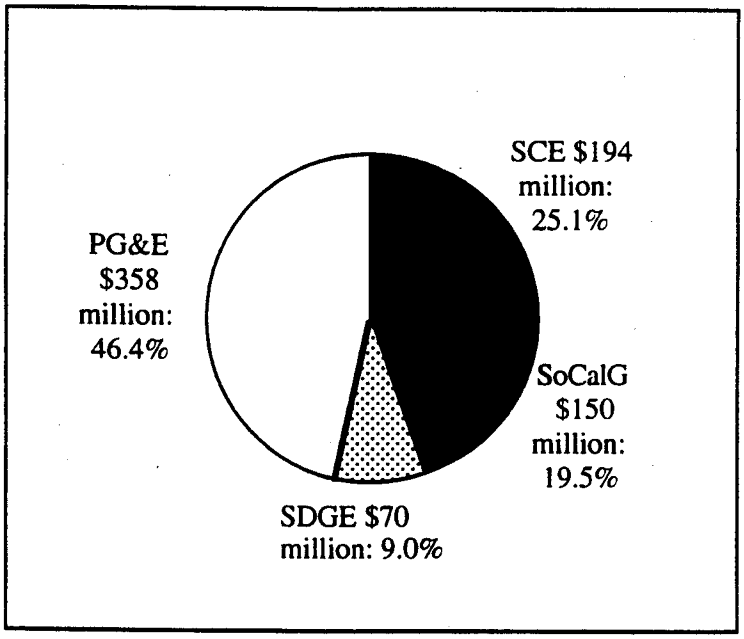
This report is organized into eight chapters and three appendices. Chapter Two provides an overview of the California utility DSM programs which are the subject of the evaluation studies. The programs are summarized in terms of extent of DSM investment, program participation, and the installation of DSM measures. Chapter Three provides a summary of *ex-post* program impact estimates to the extent they are reported at the programmatic level. Three measures of impact are summarized. These include net electrical savings (MWH or kWh), net electrical demand savings (MW or kW), and net gas savings (therms). Chapter Four provides a similar summary of impact estimates, but at the participant and/or measure level for selected measure types. Chapter Five compares *ex-post* and *ex-ante* impact estimates based on a summary of realization rates achieved. Finally, Chapter Six contains a summary of the review comments received by individual reviewers and Chapter Seven provides brief conclusions.

The report includes three appendices. Appendix A contains a bibliography with citations for each of the impact evaluation studies and annual DSM reports reviewed as part of this report. Appendix B provides an abbreviated overview of impact evaluation methodologies which have been employed in the impact evaluation studies reviewed as part of this report. Finally, Appendix C, which is separately bound, contains abstracts of each of the evaluation studies summarized as part of this report.

CHAPTER TWO
OVERVIEW OF DSM PROGRAMS

2.1 OVERVIEW OF UTILITIES AND THEIR DSM EXPENDITURES

Between 1990 and 1992, Pacific Gas and Electric Company, Southern California Edison Company, Southern California Gas Company, and San Diego Gas and Electric Company spent $772 million on energy-efficiency conservation expenditures (Division of Ratepayer Advocates, California Public Utilities Commission, 1993). The magnitude of DSM investments varies widely across the four utilities. Almost half ($358 million) of this total was expended by PG&E, the largest of the four investor-owned utilities, and less than 10 percent ($70 million) was spent by SDG&E, the smallest of the four utilities (Figure 2.1).



Source: Division of Ratepayer Advocates, California Public Utilities Commission, 1993

Figure 2.1 Total Energy-Efficiency Conservation Expenditures (in Millions of Dollars): 1990-1992

When calculated as a percent of operating revenues, these conservation expenditures do not vary widely across the four utilities. Based on the findings of Schlegel, et al. (1994), SCE spent the smallest proportion (1.1%) of its operating revenues on DSM conservation expenditures between 1990 and 1992. At the other end of the spectrum, SoCalG spent 1.7% of its operating revenues on DSM conservation expenditures.

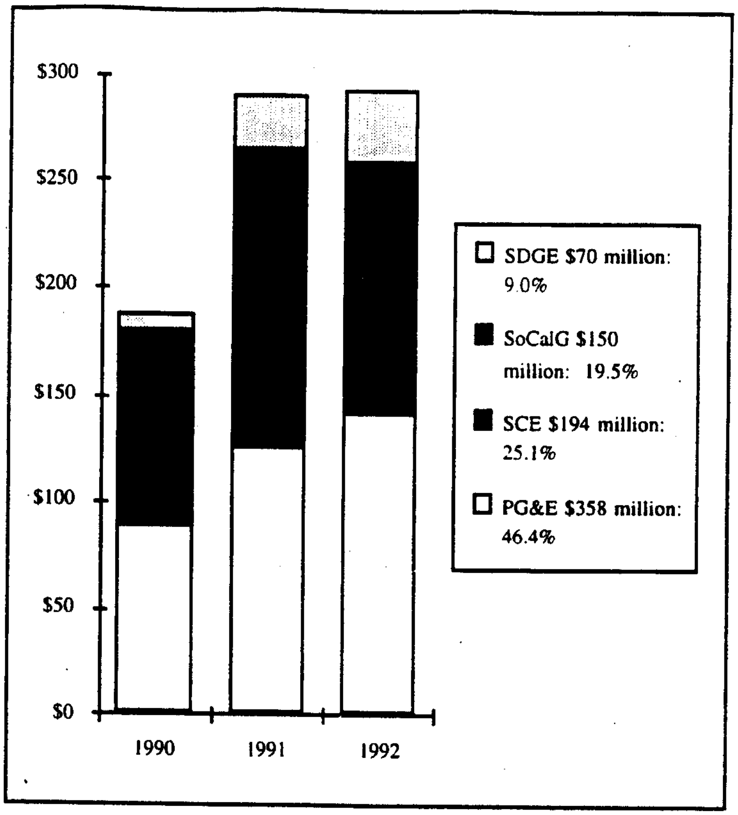
Table 2.1 DSM Conservation Expenditures as a Percent of Operating Revenues

	1990	1991	1992	Averages
PG&E				
Electric	0.9	1.3	1.7	1.3
Gas	1.3	1.4	1.5	1.4
SCE	0.8	1.2	1.3	1.1
SoCalG	1.2	2.0	1.9	1.7
SDG&E				
Electric	0.6	1.8	2.1	1.5
Gas	0.3	1.2	1.7	1.1
Averages	0.9	1.5	1.7	1.4

Source: Schlegel, et al. (1994), Figures 3-15, 3-21, 3-36, and 3-30.

As Table 2.1 and Figure 2.2 show, DSM expenditures grew rapidly between 1990 and 1991 and leveled off somewhat between 1991 and 1992. The establishment of DSM shareholder incentives for each of the four utilities was a major contributor to this observed increase in utility DSM activities. These shareholder incentives resulted in approximately $100 million in after-tax earnings for the four utilities over the three-year period (Schlegel, *et al.*, 1994).

The increase in DSM expenditures between 1990 and 1992 represents the second period of growth in DSM activities in California. In the early 1980's, California experienced a significant rise in DSM activity, spurred by regulatory pressures. This was followed by a period of decline in DSM expenditures between 1985 and 1988, corresponding with decreased regulatory interest in DSM. As a result of the growth between 1989 and 1992, three of the four utilities (PG&E, SCE, and SDG&E) have now nearly reached or exceeded the high levels of investment in DSM experienced at the end of the earlier growth period. SoCalG is the one exception. It has experienced only modest increases in its DSM expenditures in recent years, and by 1992-93, was spending less than half of the amount it had invested annually in DSM between 1983 and 1985.



Source: Division of Ratepayer Advocates, California Public Utilities Commission, 1993

Figure 2.2 Total Energy-Efficiency Conservation Expenditures (in Millions of Dollars): 1990-1992

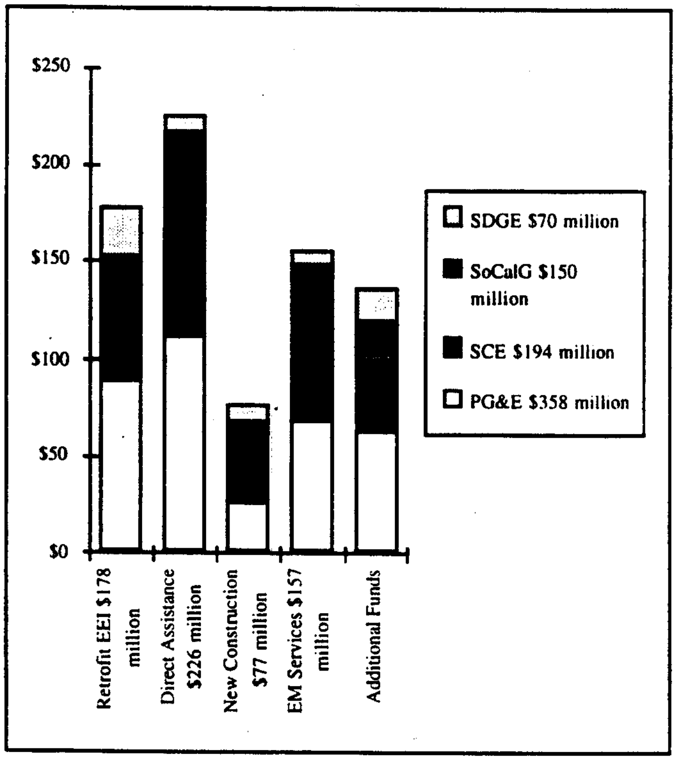
2.2 DSM EXPENDITURES BY SECTOR AND PROGRAM TYPE

The four investor-owned California utilities operate DSM programs that serve the residential, commercial, industrial, and agricultural sectors. Some programs offer rebates or other incentives to encourage participants to invest in DSM measures. Included in this category are retrofit incentive and new construction programs. These resource programs are generally viewed as viable alternative supply-side options for which the utilities are eligible to earn shared savings incentives. Other programs involve the direct installation of measures at no cost to participants. These include residential direct assistance programs for low-income households, which are viewed as equity programs. Most of the utilities are eligible to earn performance-adder incentives for operating these programs. A third type of DSM program provides energy management services such as energy audits of buildings and industrial processes. The savings of these programs are difficult to measure, even though they may be significant. As with the equity programs, utilities are eligible to earn performance-adder incentives for operating energy management services programs.

Reflecting these various programmatic differences, the CADMAC has developed the following classification scheme for DSM programs:

- Retrofit energy-efficiency incentives (residential and nonresidential)
- Residential direct assistance
- New construction (residential and nonresidential)
- Energy management services (residential and nonresidential)

Figure 2.3 indicates that residential direct assistance programs account for the largest percentage of DSM expenditures of the four types of programs, accounting for 29% ($226 million) of the total. Retrofit energy-efficiency incentives and energy management services account for the next largest percentages, with $178 and $157 million, respectively. New construction programs represent the smallest type, with only $77 million, or 10% of the total expenditure.



Source: Division of Ratepayer Advocates, California Public Utilities Commission, 1993

Figure 2.3 Total Energy-Efficiency Conservation Expenditures by Program Type (in Millions of Dollars): 1990-1992

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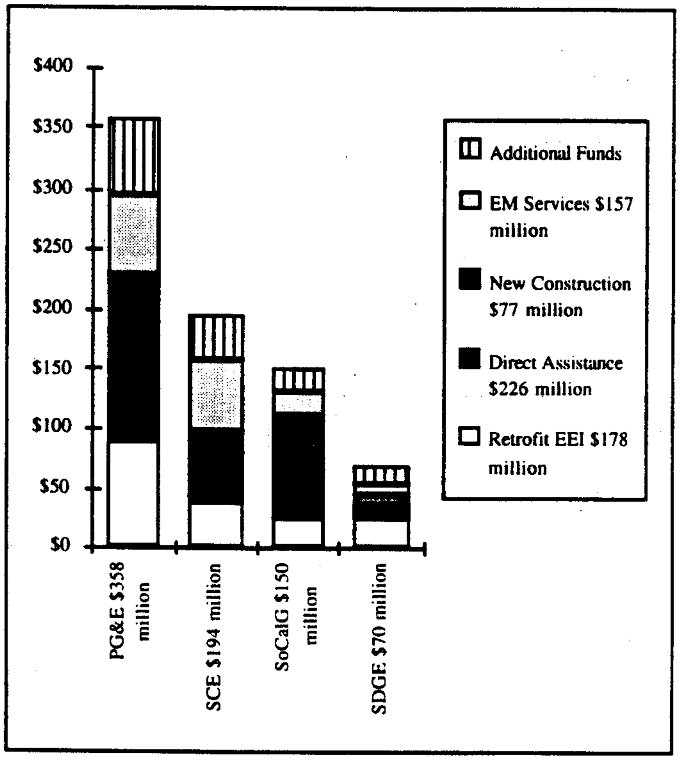
Figure 2.4 shows the allocation of each utility's DSM expenditures across the four types of programs. There are several noteworthy differences across the utilities. In particular, PG&E and SCE spend especially high proportions of their total DSM budgets on energy management services programs. SoCalG, in contrast, dedicates a large proportion of its total DSM expenditures to its residential direct assistance programs.



Source: Division of Ratepayer Advocates, California Public Utilities Commission, 1993

Figure 2.4 Total Energy-Efficiency Conservation Expenditures by Utility (in Millions of Dollars): 1990-1992

2.3 OVERVIEW OF PROGRAM PARTICIPATION LEVELS

The set of 1990-92 impact studies provide a basis for describing the magnitude of the California DSM activities in terms of program participation levels (described in this section) and numbers of measures distributed (described in section 2.4). The impact studies do not report participant or measure penetration levels for every DSM program, nor do all the impact studies cover all three years.[1] As a result, the data presented in the following figures should be viewed as illustrative and not as a complete inventory.

[1] The data on numbers of participants are annualized, so that comparisons can be made across impact studies that cover different time periods. For example, 21,976 households participated in PG&E's Ceiling

Impact evaluations of 11 residential retrofit energy-efficiency incentive programs were conducted, spanning all four utilities (Figure 2.5). Included among these programs are residential weatherization, ceiling insulation, appliance efficiency, compact fluorescent, and low-flow showerhead programs. These programs served almost 400,000 participants on an annual basis during the 1990-92 time frame. The compact fluorescent lighting programs account for approximately half of these participants. Programs offering incentives for the purchase of energy-efficient central air-conditioning units and refrigerator replacements account for the largest share of the remaining participants.

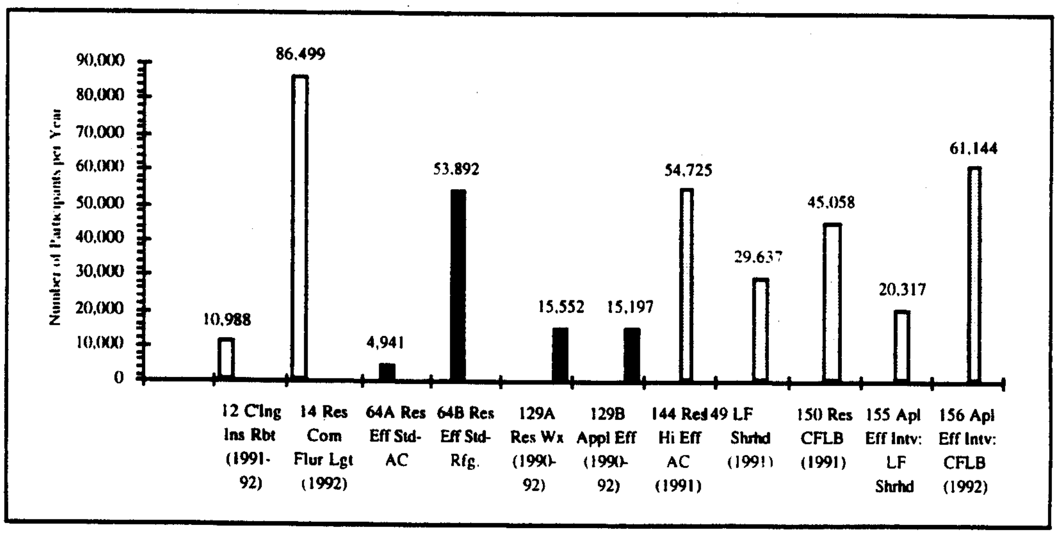


Figure 2.5 Number of Participants in Residential Retrofit Programs

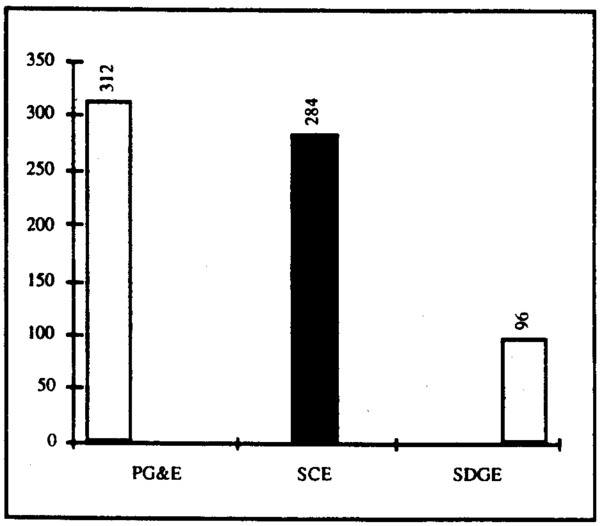


Figure 2.6 Number of Participants in Nonresidential New Construction Programs

Insulation Rebate Program during 1991 and 1992. The annualized participation level reported in this chapter, therefore, is 10,988.

Levels of participation in new construction programs are much smaller than in retrofit programs, reflecting the lower level of utility expenditures dedicated to these programs. Figure 2.6 shows that the number of participants in 1992 nonresidential new construction programs operated by three of the four utilities, ranged from 96 in SDG&E's program to 312 in PG&E's program. Several of the utilities also operate residential new construction programs that provide financial incentives and technical assistance to builders to construct homes that exceed Title 24 standards. Precise levels of participation in these programs are not reported in the impact evaluations, but they are significantly larger than the numbers shown in Figure 2.6, partly because incentive payments per home are much smaller than the average utility cost per participant in nonresidential new construction programs.

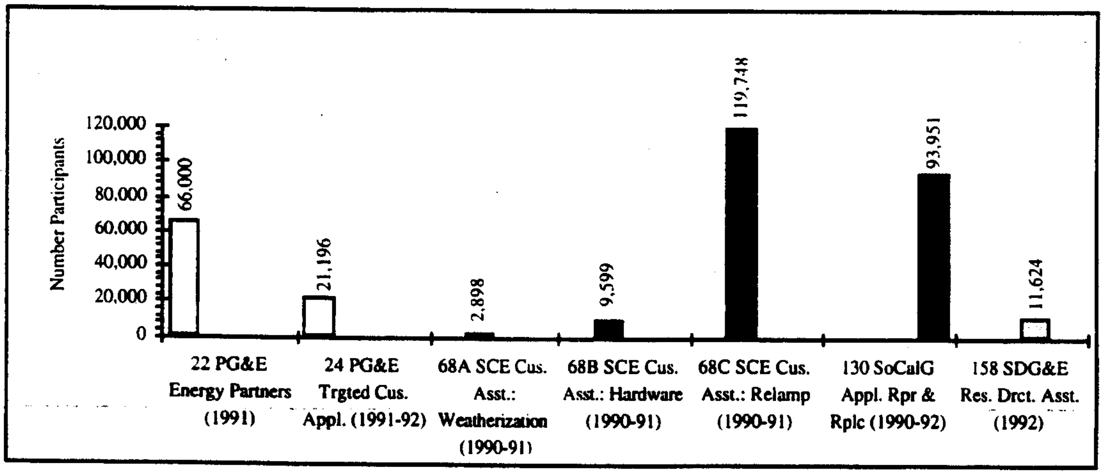


Figure 2.7 Number of Participants in Direct Assistance Programs

As noted previously, overall levels of expenditures across the four types of programs are greatest for residential direct assistance programs. Based on participation levels for seven of these programs (see Figure 2.7), nearly 186,000 low-income households participated in these programs each year between 1990 and 1992. These programs range from relamping efforts (which accounted for 59,874 of SCE's participants each year) to more substantial weatherization and appliance repair and replacement programs, which served most of the remaining participants.

Each of the four utilities operated a residential energy management services (EMS) program between 1990 and 1992. The magnitude of these programs are characterized in Figure 2.8. Altogether, approximately 222,000 households participated in these programs each year, receiving home audits, energy information, and/or low-cost measures such as low-flow showerheads or compact fluorescent lamps. The largest of these programs is operated by SCE, which accounts for nearly half of these participants.

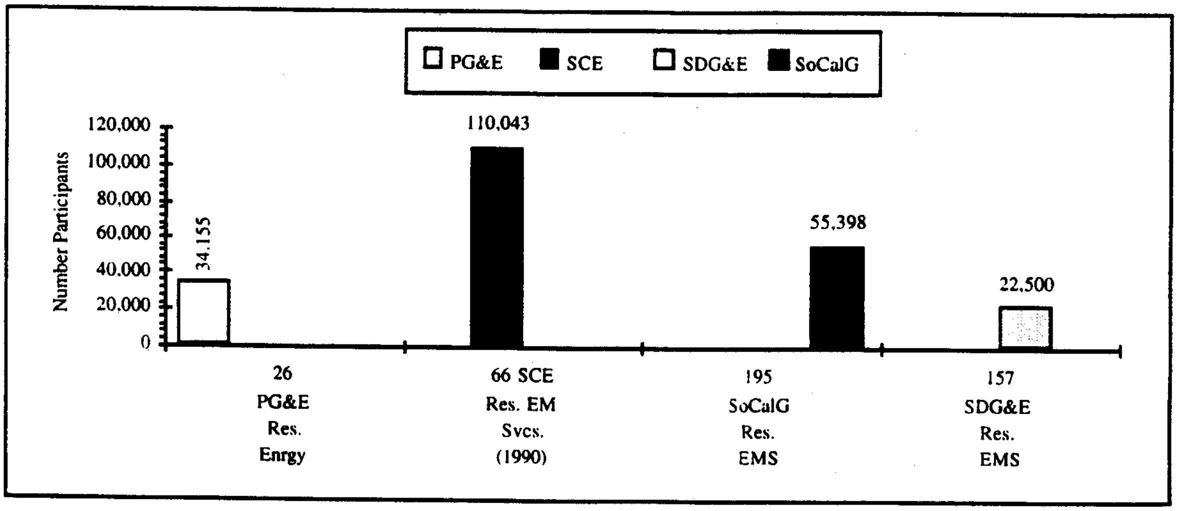


Figure 2.8 Number of Participant in Residential Energy Management Services Programs

Nonresidential energy management services programs operated by the four utilities served approximately half as many participants in 1992 (totaling 111,000) as their residential EMS program counterparts. As with the residential EMS programs, SCE delivered energy management services to the largest number of nonresidential customers. In 1992, for example, SCE completed 56,022 commercial audits, 9,330 industrial audits, and 6,596 agricultural audits (Figure 2.9). At the other extreme, SDG&E completed only 4,175 commercial and industrial audits during the same year.

Based on the numbers of participants itemized in Figures 2.5 through 2.9, the four California utilities served more than 900,000 participants annually, during the 1990-92 period. Since a participant may take advantage of two or more of a utility's programs, the unduplicated number of participants is undoubtedly less than 900,000. Nevertheless, these figures indicate that an impressive number of customers have benefited from California's DSM programs.

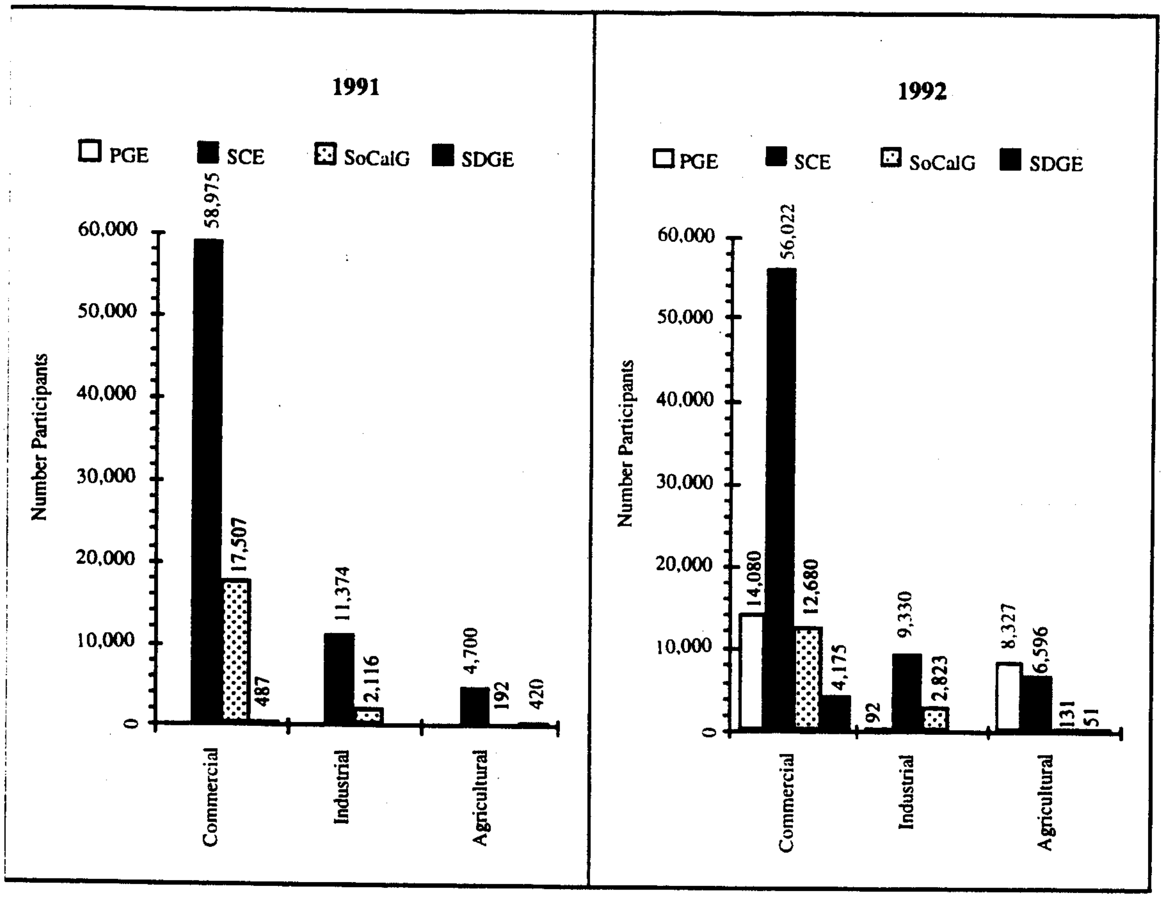


Figure 2.9 Number of Participants in Nonresidential Energy Management Services Programs

2.4 OVERVIEW OF INSTALLATION LEVELS FOR SELECTED MEASURES

In addition to comparing the levels of DSM expenditures and the numbers of DSM program participants across utilities, it is possible to compare the numbers of DSM measures distributed for a small subset of measures: compact fluorescent lamps, low-flow showerheads, and refrigerator replacements.

Compact fluorescent lamps would appear to be the DSM measure that was distributed to the greatest number of customers between 1990 and 1992. In particular, the annualized numbers shown in Figure 2.10 indicate more than 775,000 lamps were distributed each year by the three utilities that deliver electric services: PG&E, SCE, and SDG&E. Between 200,000 and 300,000 lamps were distributed annually by each of these utilities. The average number of compact fluorescent lamps delivered per household ranged across programs from 1.0 to 4.6.

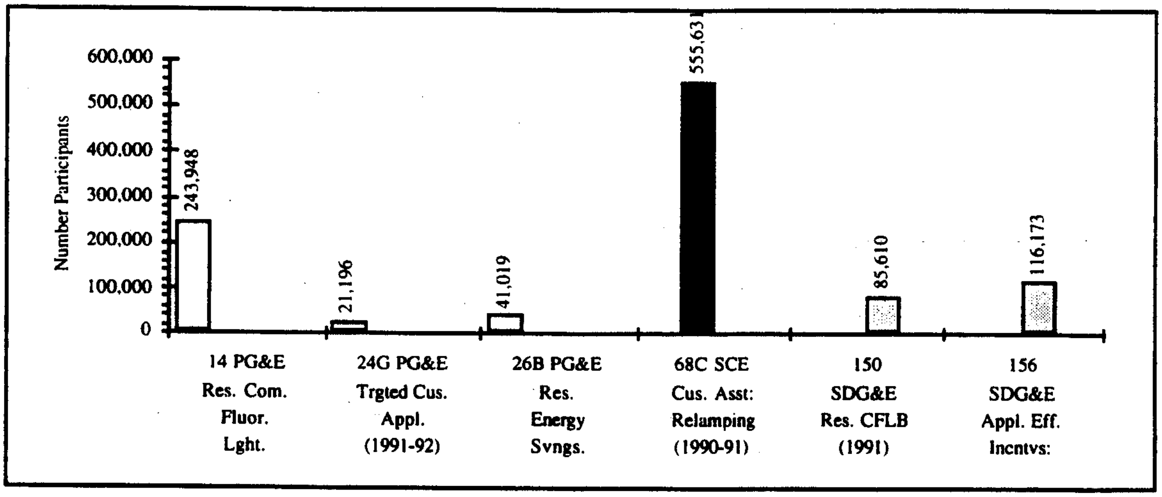


Figure 2.10 Number of Compact Fluorescent Lamps Distributed

All four utilities operate one or more programs that include the distribution of low-flow showerheads; however, data on numbers of measures installed are available for only two utilities: PG&E and SDG&E. The numbers reported in Figure 2.11 suggest that these utilities distributed more than 120,000 low-flow showerheads on an annual basis during the three-year study period.

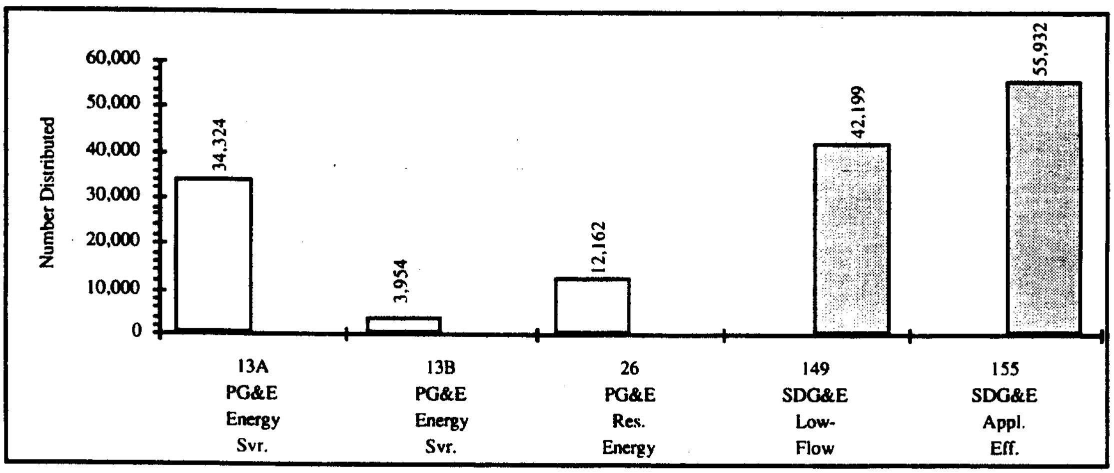


Figure 2.11 Number of Low-Flow Showerheads Distributed

Refrigerator replacements are a feature of the DSM programs operated by three of the four utilities (specifically, those that provide electric services). The three programs listed in Figure 2.12 contributed to the purchase of nearly 123,000 energy-efficient refrigerators each year between 1990 and 1992.

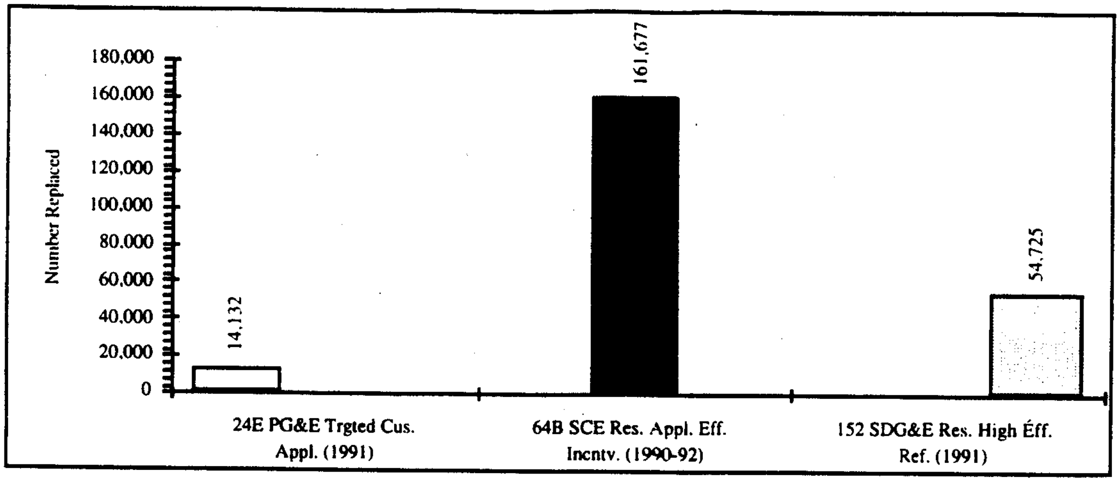


Figure 2.12 Number of Refrigerator Replacements

Based on the measure penetration rates itemized in Figures 2.10 through 2.12, the four California utilities have had a significant impact on the purchase and installation of energy-efficient equipment and materials in the State. Undoubtedly this has been responsible for generating region-wide consumer demand for DSM products and for strengthening the wholesale and retail infrastructures that promote their distribution beyond the immediate participants in DSM programs.

CHAPTER THREE SUMMARY OF *EX-POST* PROGRAM IMPACT ESTIMATES BY PROGRAM

3.1 INTRODUCTION

This chapter, along with Chapter Four, summarizes energy and demand savings as reported in the individual utility evaluations studied. This chapter summarizes estimated savings at the programmatic level (where available), while Chapter Four summarizes savings reported at the participant or measure level. The focus is on net electrical energy savings (MWH or kWh), net electrical demand savings (MW or kW), and net gas savings (therms).

Before proceeding to summarize the savings estimates reported, several important points must be made. These can be summarized as follows:

- Consistent savings estimation approaches were not used across the four utilities, or even within single utilities. Consequently, it often proved difficult or impossible to systematically compare estimates of savings on the same dimensions.

- The savings reported vary by time frame. Some studies reported savings for a single year, while others reported savings for multiple years or parts of years. Where possible, the authors attempted to annualize the savings, if this could be done with a reasonable degree of confidence. If not, the savings are reported for the period covered by the study.

- Savings estimates and evaluation methods vary by sector. In many cases, significantly different approaches were employed to estimate savings for residential programs and commercial, industrial, and agricultural programs.

- Savings were reported at many different levels of aggregation. Some savings were reported for the program as a whole. In other cases, savings were reported on a per measure basis (e.g. per refrigerator replaced). In other cases, savings were reported on a per participant basis. In some cases, savings were reported by measure class (e.g.

lighting as a measure class category in commercial buildings as opposed to per fixture). Savings were also sometimes reported on a per building or per average building basis.

- Reported savings varied by unit of measurement. Some studies reported savings on a megawatt hour per year basis. In other cases, average monthly kilowatt hours were reported. And yet another variant, watts per measure were reported, while a separate study estimated the number of hours each measure was used.

- Finally, the ways savings were reported tended to vary by the evaluation method employed. Conditional demand analysis, for example, often reported results in terms of units such as average monthly kilowatt hours, while building simulation modeling would report estimated savings per building, or per average building, disaggregated to measure classes.

Because of the significant variation in the ways savings were reported, extreme caution should be used in attempting to compare across studies or to aggregate savings. Wherever possible, the authors attempted to normalize the reported savings through simple calculation. In each case, the authors attempted to carefully label the savings as reported in the individual studies.

3.2 SUMMARY OF RESIDENTIAL PROGRAM SAVINGS

Figure 3.1 summarizes electrical energy savings reported for residential retrofit incentive programs. Southern California Edison's Customer Assistance Program for 1990-1991 (Study No. 68), which included weatherization (1,539), hardware (4,521), and relamping incentives (18,321), reported a total of 24,381 megawatt hours per year. This was followed by PG&E's Residential Compact Fluorescent Lighting Program (Study No. 14), which reported electrical energy savings of 13,807 megawatt hours per year.

Figure 3.2 summarizes gas savings for the residential retrofit incentive programs. Southern California Gas' Residential EMS Program (Study No. 195) reported savings of 1,693,000 therms per year. This was followed closely by San Diego Gas and Electric's Appliance Efficiency Incentives and Residential Weatherization programs (Study Nos. 155 and 129A).

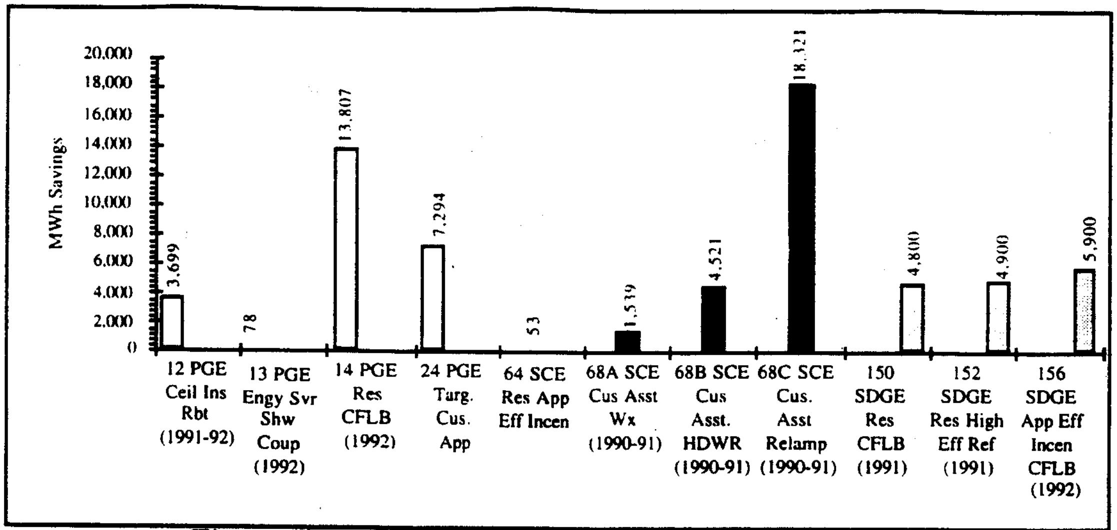


Figure 3.1 MWh Savings Reported by Program: Residential Retrofit Programs

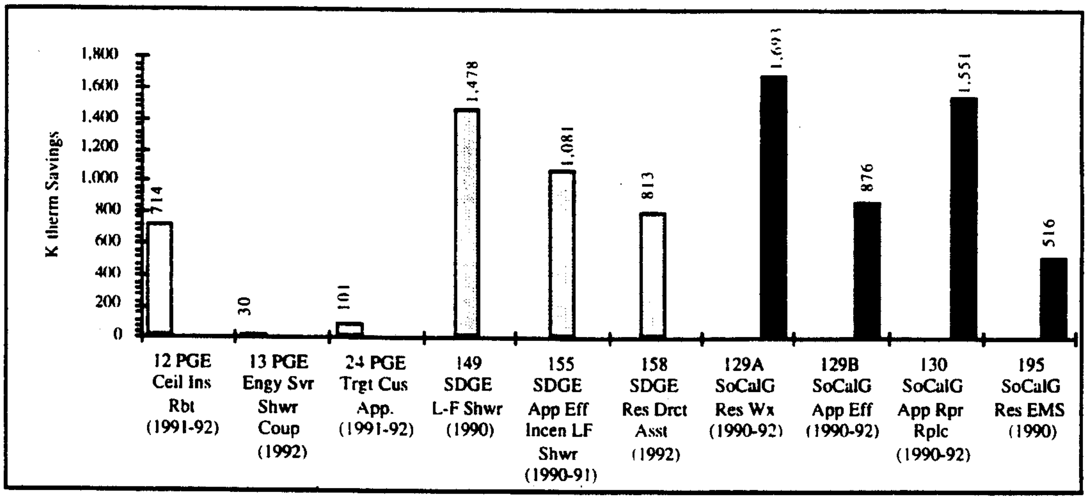


Figure 3.2 Kilotherm Savings Reported by Program: Residential Retrofit Programs

3.3 SUMMARY OF COMMERCIAL, INDUSTRIAL, AND AGRICULTURAL PROGRAM SAVINGS

This section summarizes the savings reported for commercial, industrial, and agricultural (C/I and A) programs, where they were reported at the program level. Figure 3.3 summarizes net electrical energy savings. PG&E's Commercial, Industrial, and Agricultural Retrofit Rebate Program for the period 1991-1992 (Study No. 43) reported over 663,000 megawatt hours of savings.

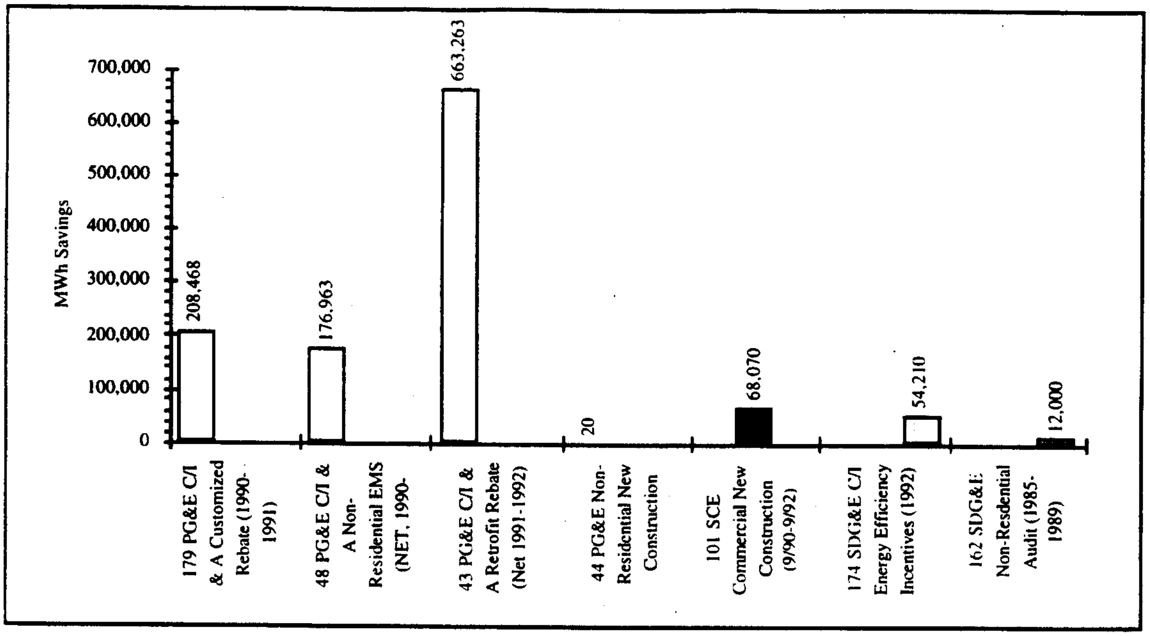


Figure 3.3 MWh Savings Reported by Program: Commercial, Industrial and Agricultural Programs Reported

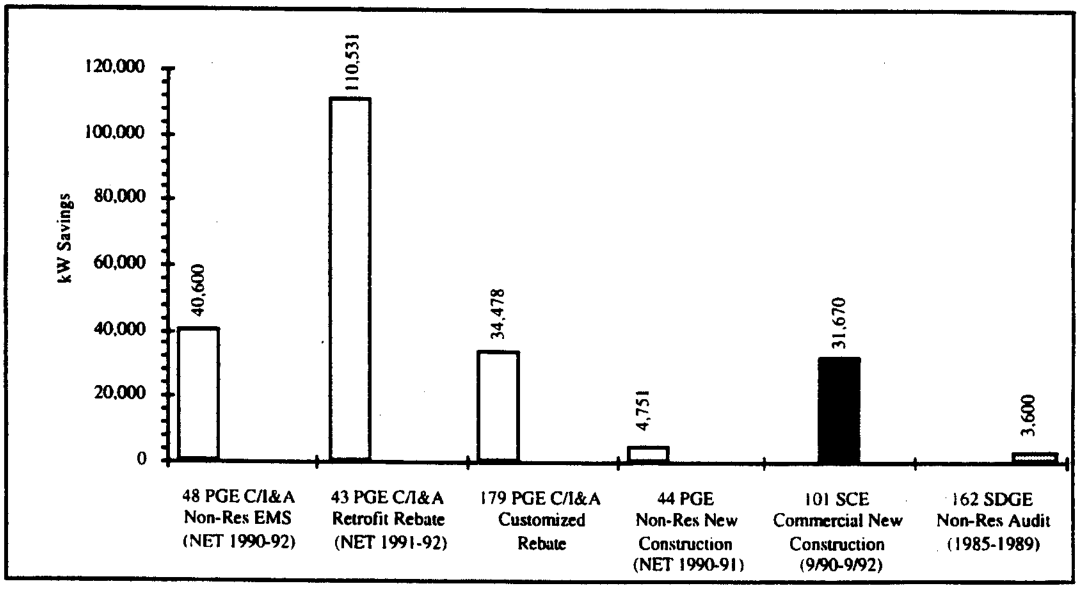


Figure 3.4 kW Savings Reported by Program: Commercial, Industrial and Agricultural Programs Reported

Figure 3.4 summarizes electrical demand savings reported at the program level. Again, PG&E's Commercial, Industrial, and Agricultural Retrofit Rebate Program reported a total of 110,531 kilowatts of demand savings (Study No. 43) for the 1991-1992 period.

Figure 3.5 reports C/I and A programmatic gas savings. Only two studies reported total therm savings at the programmatic level. PG&E, in Study No. 48, reported a total of 2,572,000 therms of net gas savings for the Non-residential EMS Program for the period 1990-1992. San Diego Gas and Electric reported a total of 139,977 therms of gas savings for their nonresidential audit program (Study No. 162) over the period 1985-1989.

In some cases, programmatic savings in the C/I and A sector were reported at the sectoral level (e.g. commercial, industrial, and agricultural). Commercial sector results are summarized in Figures 3.6, 3.7, and 3.8, which report megawatt hour, kilowatt and therm savings respectively. Similarly, industrial sector savings are shown in Figures 3.9, 3.10, and 3.11, while agricultural sector savings are reported in Figures 3.12 and 3.13.

Based on these results for PG&E, the commercial sector would appear to offer the greatest potential for electrical energy savings, followed by the industrial and the agricultural sectors. The exception to this is in kW savings, where the agricultural sector appears to out perform the industrial sector in the demand savings delivered (primarily through the demand savings associated with irrigation pumping measures). It should be noted, that with one exception, all of the sectoral programmatic results are reported by PG&E.

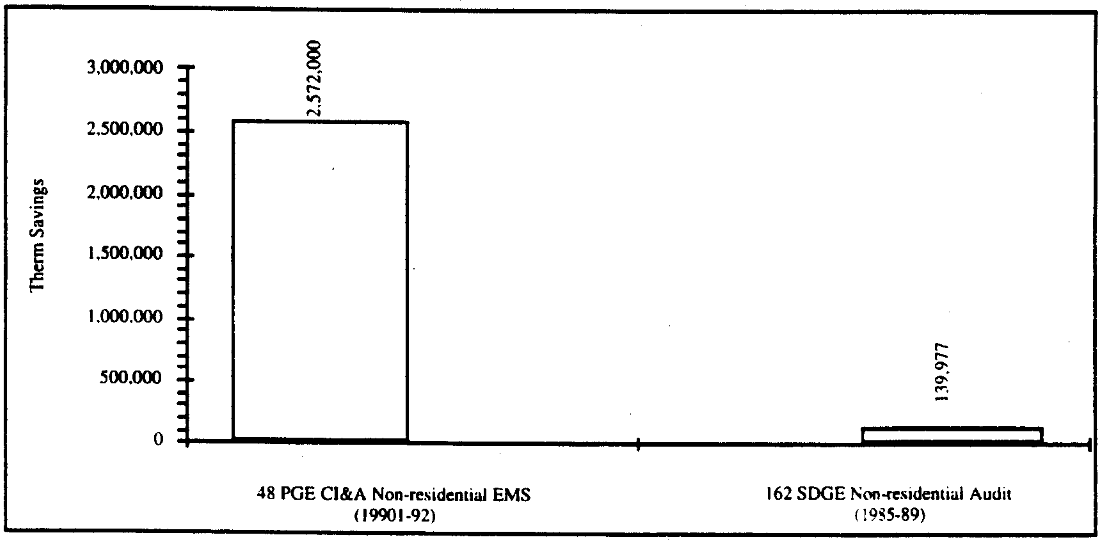


Figure 3.5 Therms Savings Reported by Program: Commercial, Industrial and Agricultural Programs Reported

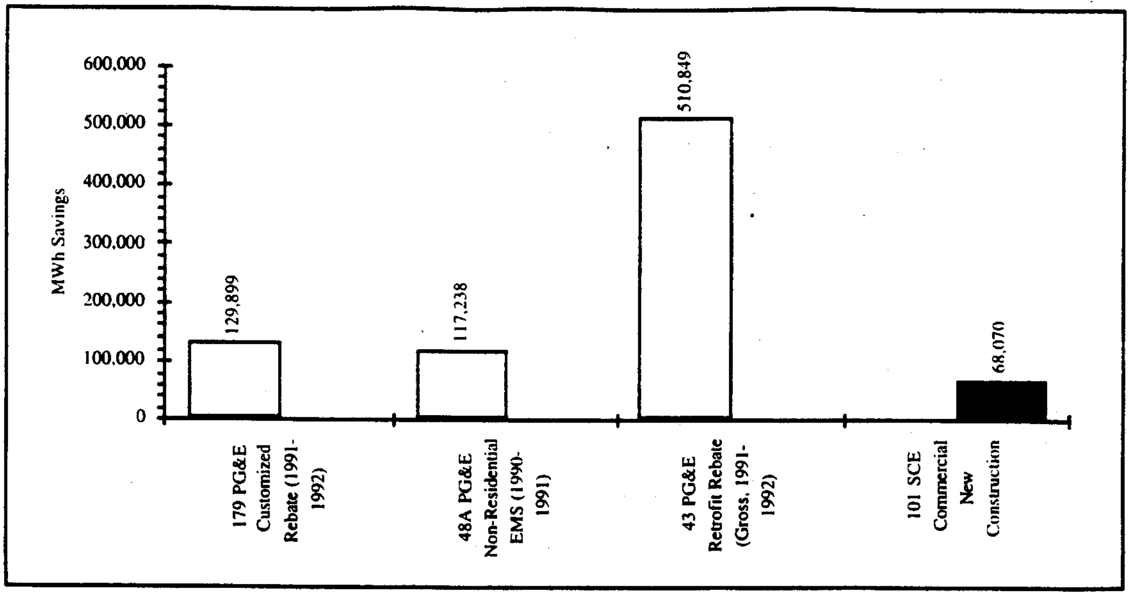


Figure 3.6 MWh Savings Reported by Sector: Commercial Programs

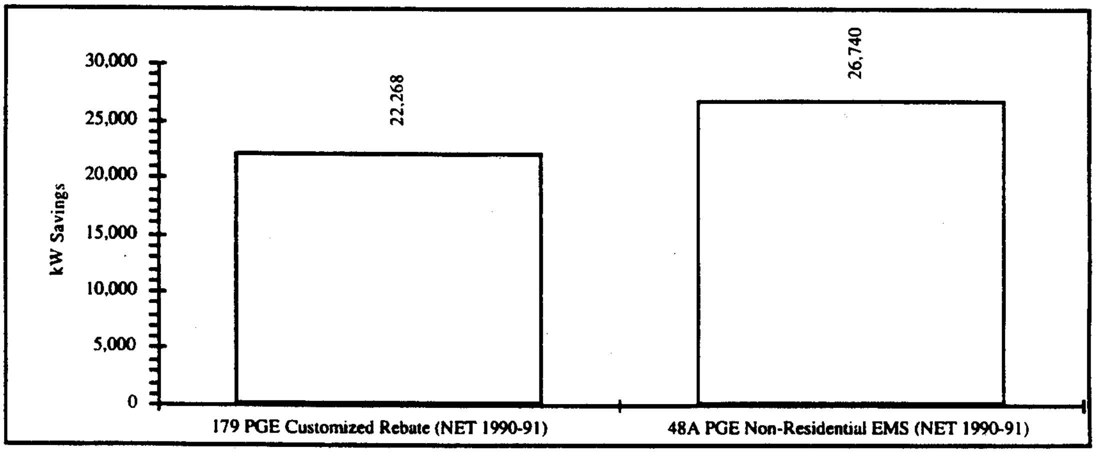


Figure 3.7 kW Savings Reported by Sector: Commercial Programs

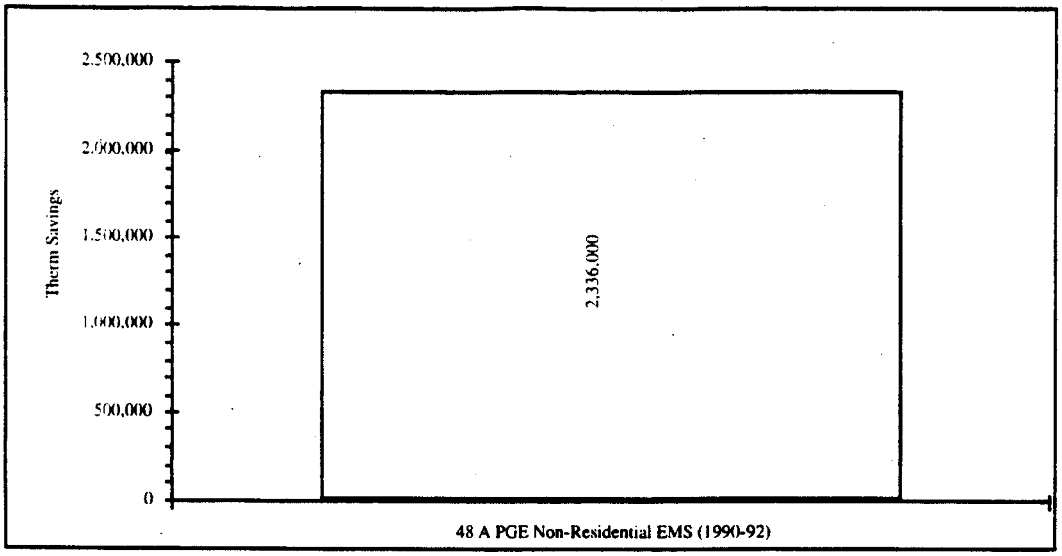


Figure 3.8 Therms Savings Reported by Program: Commercial Programs

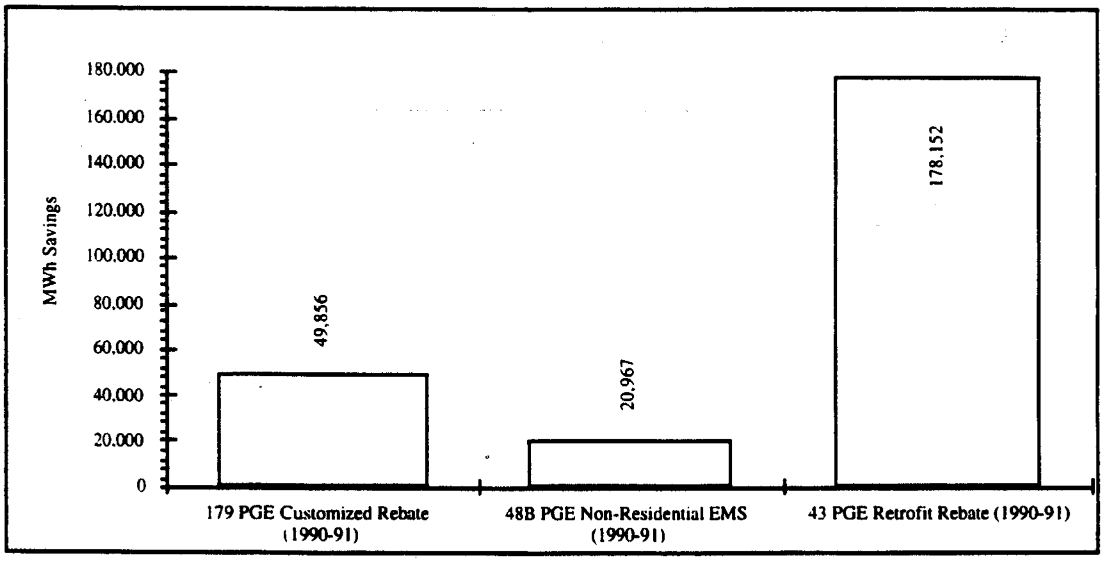


Figure 3.9 MWh Savings Reported by Sector: Industrial

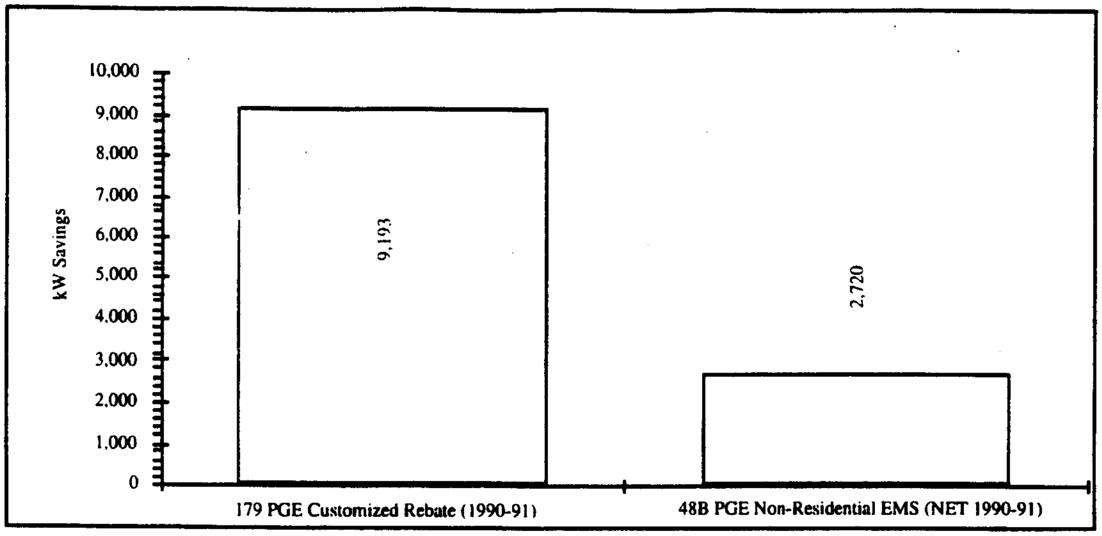


Figure 3.10 kW Savings Reported by Sector: Industrial Programs

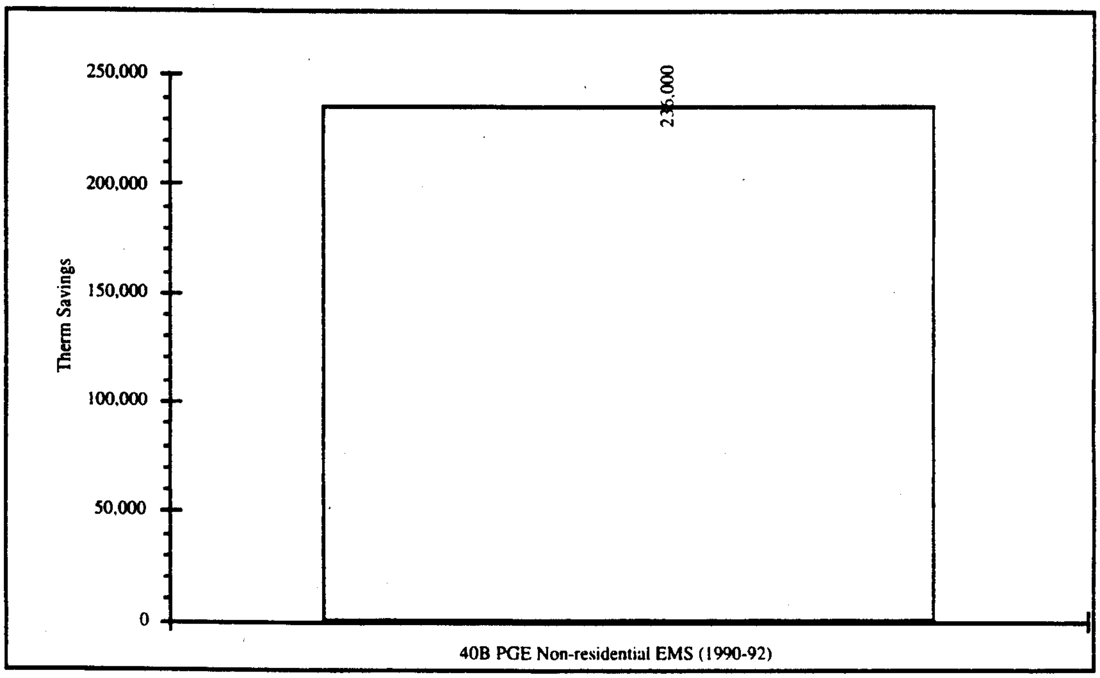


Figure 3.11 Therms Savings Reported by Program: Industrial

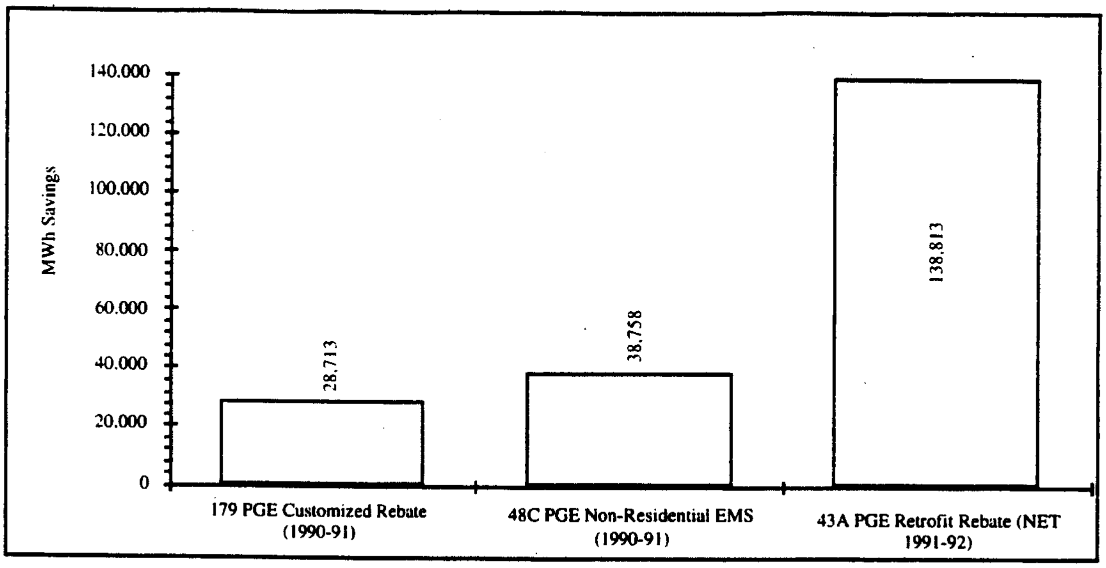


Figure 3.12 MWh Savings Reported by Sector: Agricultural Programs

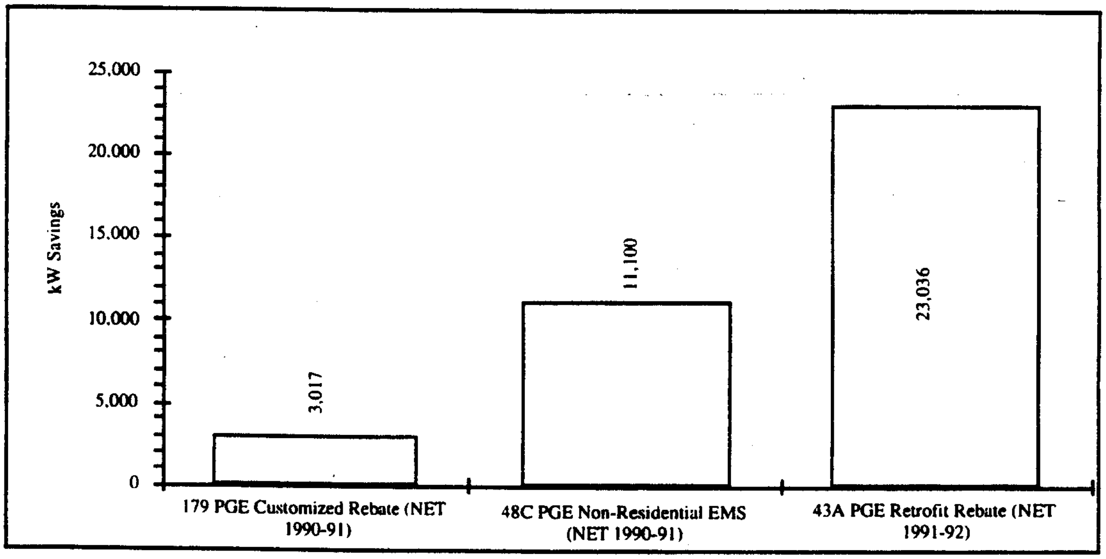


Figure 3.13 kW Savings Reported by Sector: Agricultural Programs

CHAPTER FOUR
SUMMARY OF *EX-POST* PROGRAM IMPACT ESTIMATES AT THE PARTICIPANT AND MEASURE LEVEL

Chapter Three summarized savings which were reported at the programmatic level, that is, megawatt hour, kilowatt, and therm savings were aggregated to the whole program. Many of the evaluation studies also reported savings on a per measure or per participant basis, in addition to the aggregated programmatic savings. Other evaluation studies only reported savings at the measure or participant level. This chapter provides a summary of savings reported for selected measures or measure categories.

4.1 RESIDENTIAL PROGRAMS

As examples of measure savings reported in the residential sector, savings for refrigerator, residential lighting, and low-flow showerhead measures are summarized.

Figure 4.1 summarizes megawatt hour savings reported for energy efficient refrigerators across three utilities. Southern California Edison (Study No. 64) reported refrigerator related savings of 46,240 megawatt hours, or correspondingly, 286 kilowatt hours per refrigerator measure as can be seen in Figure 4.2. The range of residential refrigerator related savings, both at the per measure and program level, underscore the differences in program type, evaluation method, and time periods covered by the evaluation studies, as they vary widely (e.g., 90 kWh to 392 kWh per refrigerator measure over a 1-2 year period).

Figures 4.3 and 4.4 provide similar comparisons for residential lighting measures. Again, a wide variation of kilowatt hour savings is reported (34 kilowatt hours to 128 kilowatt hours) per lamp underscores differences in actual savings as well as differences caused by program type, evaluation method, and time period covered, as well as other factors.

Figure 4.5 reports similar savings results for low-flow showerheads. In this case, the therm savings per measure reported by PG&E and SDG&E vary substantially. Only one program reported electrical savings per low flow showerhead installed. PG&E's E-Saver Showerhead Coupon Program reported a savings of 78.3 kWh in 1992 per showerhead installed.

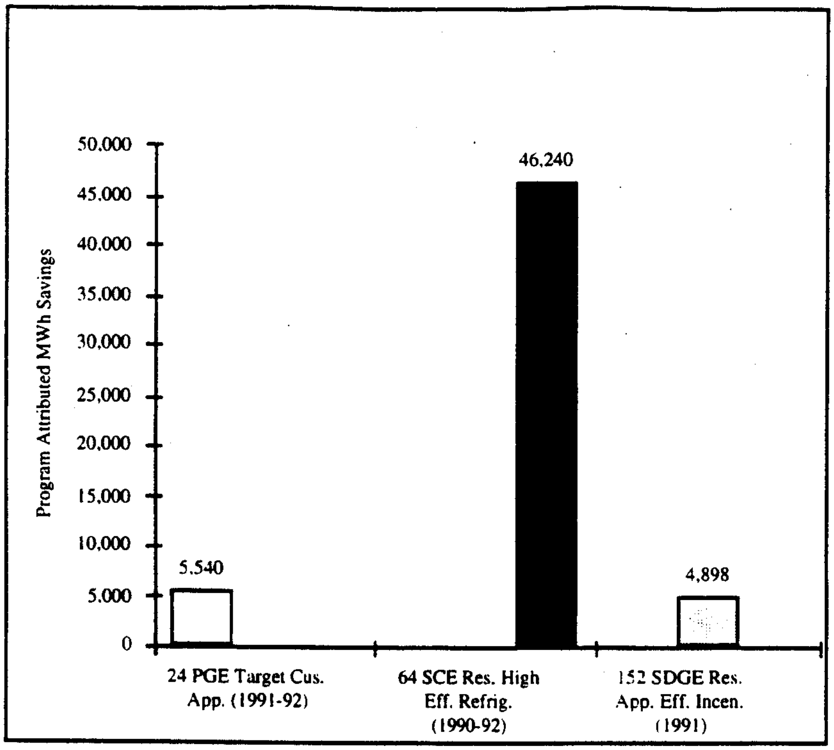


Figure 4.1 Savings Reported per Refrigerator Replacement Program

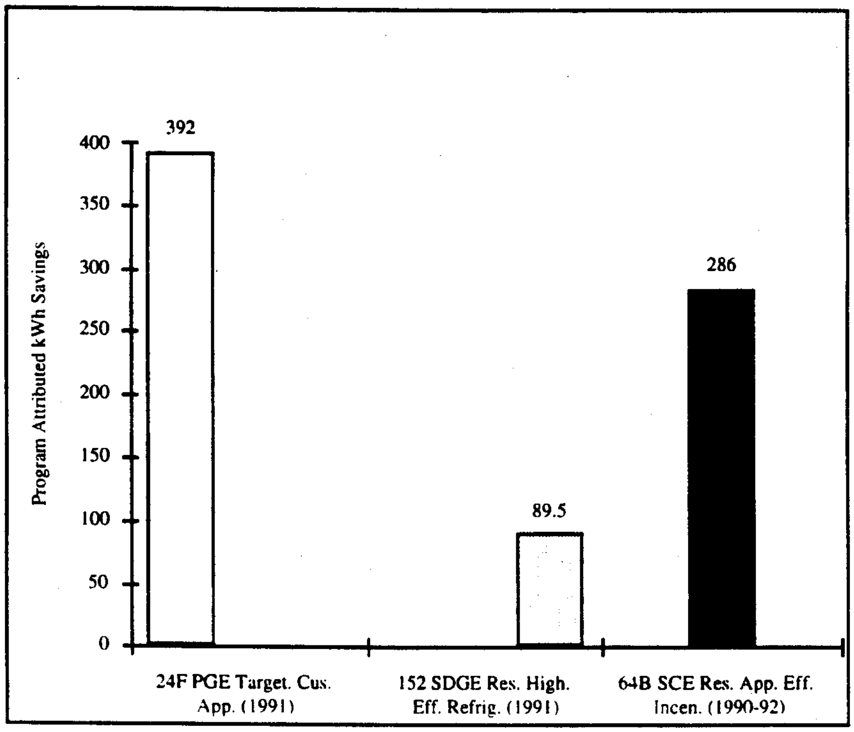


Figure 4.2 Savings Reported per Refrigerator Replaced

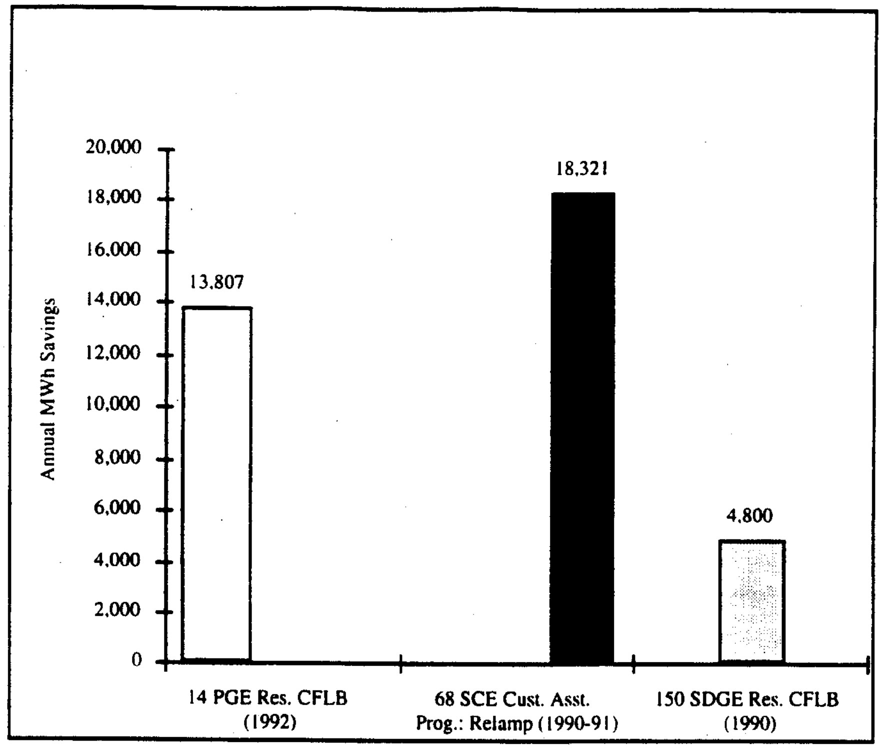


Figure 4.3 Savings Reported per Residential Lighting Program

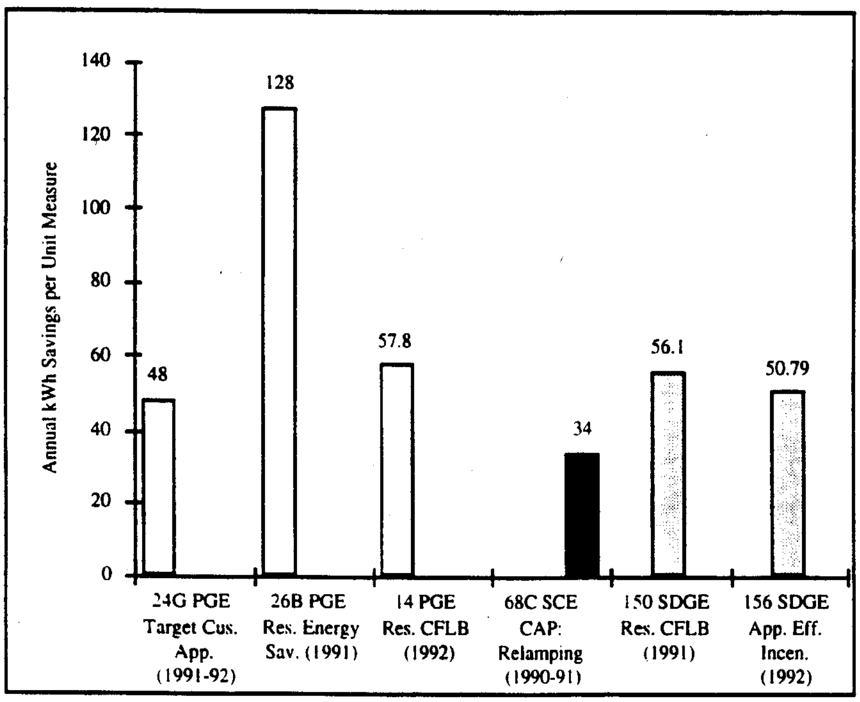


Figure 4.4 Savings Reported per Residential CFLB

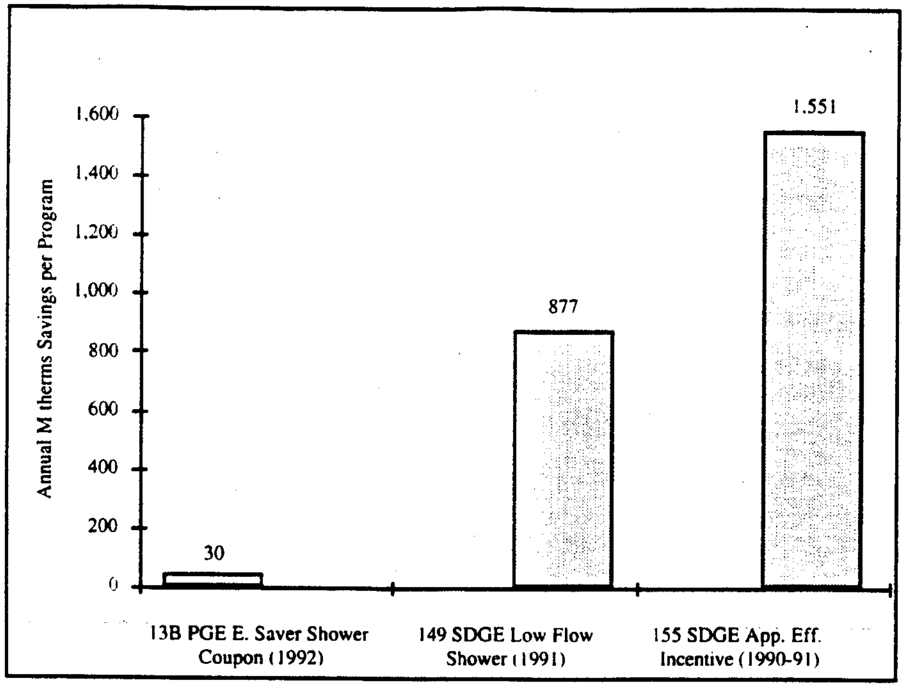


Figure 4.5 Savings Reported per Residential Low-Flow Showerhead Program (Therms)

4.2 COMMERCIAL, INDUSTRIAL, AND AGRICULTURAL PROGRAMS

Southern California Edison reported measure level savings for their 1990 Energy Management Services and Hardware Rebate Program (Study Nos. 87, 88, 92, 94, and 95). These results for selected measure types applicable to the commercial, industrial, and agricultural sectors are reported in Figures 4.6 and 4.7. Figure 4.6 reports estimated annual kilowatt hour savings for the indicated measure category. Of the common measures selected for presentation in this report, lighting reflectors and HVAC energy management systems reported the largest savings at 96,960 kilowatt hours and 90,276 kilowatt hours respectively. Similarly, of the selected measures compared for demand savings, lighting reflectors again delivered the largest demand savings (19 kW) followed by indoor lighting systems at 14.5 kW (see Figure 4.7).

Figure 4.8 summarizes annual gas savings per unit for selected measure types in the commercial, industrial, and agricultural sector. The results are reported by Southern California Gas across two studies (Study No. 137, High Efficiency Commercial Equipment and Study No. 139, Industrial Demand Side Management). The figure demonstrates that the largest gas savings from the measures compared derived from commercial boilers at 1,979,495 therms and commercial cooking equipment at 1,105,402 therms. In the industrial sector, Southern California Gas reports that of the selected measures analyzed in this report, industrial furnaces deliver the greatest gas savings at 183,168 therms followed by industrial boilers at 89,153 therms. Savings covered the program years 1990-1992.

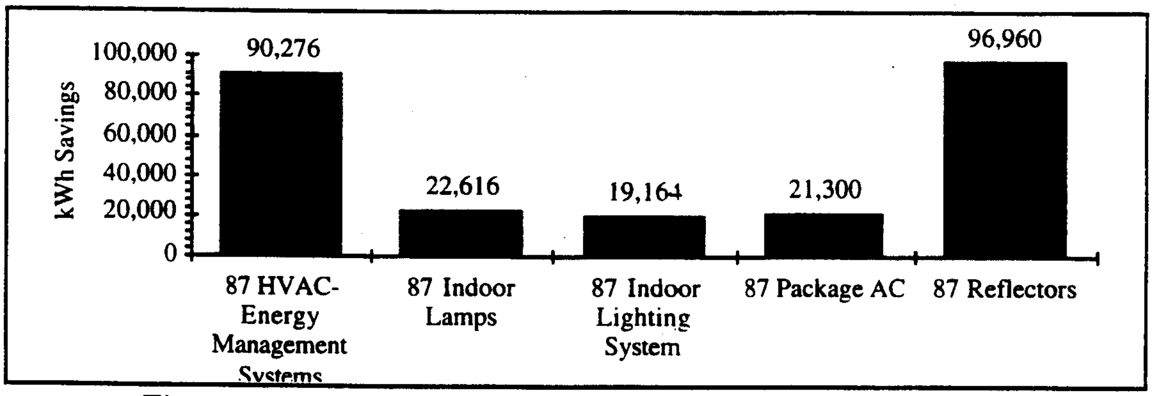


Figure 4.6 kWh Savings Reported by CIA Measure Class

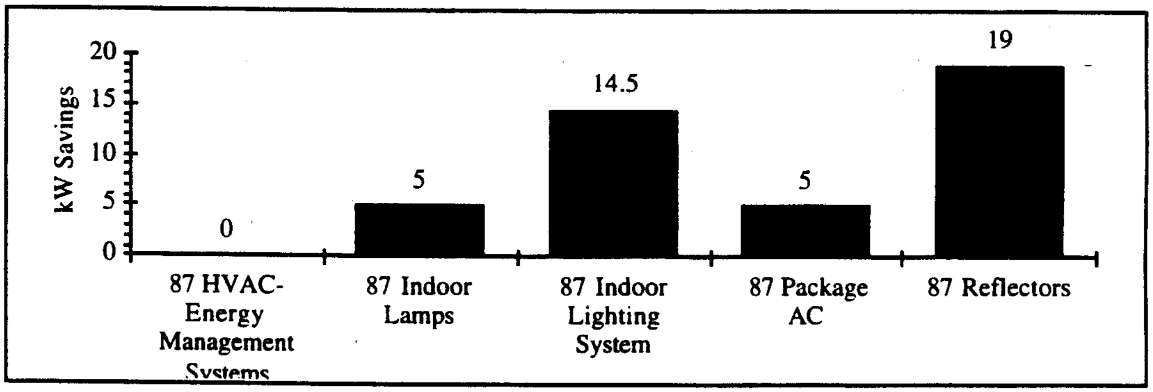


Figure 4.7 kW Savings Reported by CIA Measure Class

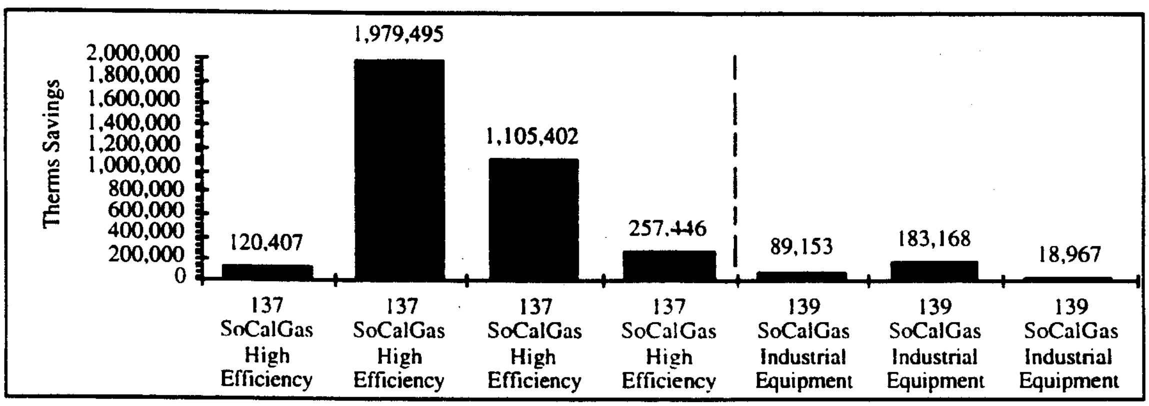


Figure 4.8 Therm Savings Reported by CIA Measure Class

CHAPTER FIVE
COMPARISON OF EX-POST AND EX-ANTE IMPACT ESTIMATES

A primary purpose of the DSM impact evaluations described in this report is to determine whether or not any systematic biases exist in the *ex-ante* estimates of program savings and cost-effectiveness. Identification of systematic biases can lead to improvements in program design, more effective resource planning assumptions, and incentive payments that better reflect program benefits.

This chapter assesses the relationship between *ex-ante* and *ex-post* estimates of energy savings. Realization rates (the ratio of *ex-post* to *ex-ante* estimates of savings) are used as the main method of assessing bias. We begin by describing the realization rates of all the programs and program segments studied, and compare these across utilities (Section 5.1) Attention then turns to an analysis of realization rates by sector and program type (Section 5.2). After describing the realization rates that resulted from different evaluation methods (Section 5.3), the chapter ends by focusing on the realization rates associated with three specific DSM measures (Section 5.4). As the chapter moves from an aggregate level of analysis to a focused assessment of specific measures, greater explanation of variations in realization rates is possible.

5.1 REALIZATION RATES IN AGGREGATE

The realization rates associated with 158 programs and program segments are examined in this section. PG&E programs account for almost half of these rates (Table 5.1), which is consistent with the fact that they spent 46% of the DSM expenditures of these four utilities during the 1990-92 period. SDG&E, on the other hand, accounts for 18% of the realization rates, while they spent only 9% of the DSM expenditures.

The realization rates range widely from the low values for PG&E's Energy Saver Showerhead Coupon Program of 0.03 (the electric component) and 0.05 (the gas component) to 14.54 for the boiler component of SoCalG's High Efficiency Commercial Equipment Program. The distribution of these rates is highly skewed, with 62% falling within a narrow range from 0.5 to 1.25, but with several surpassing 4.0 (Figure 5.1). The median value of this distribution is 0.86. Thus, on average, 86% of the projected savings from these programs were realized.[2]

Table 5.1 Median Realization Rates by Utility

	Median Value of Realization Rates	Number of Programs or Program Segments
All programs and program segments	0.86	158
PG&E	0.82	73
SCE	0.87	24
SoCalG	0.66	32
SDG&E	0.67	28

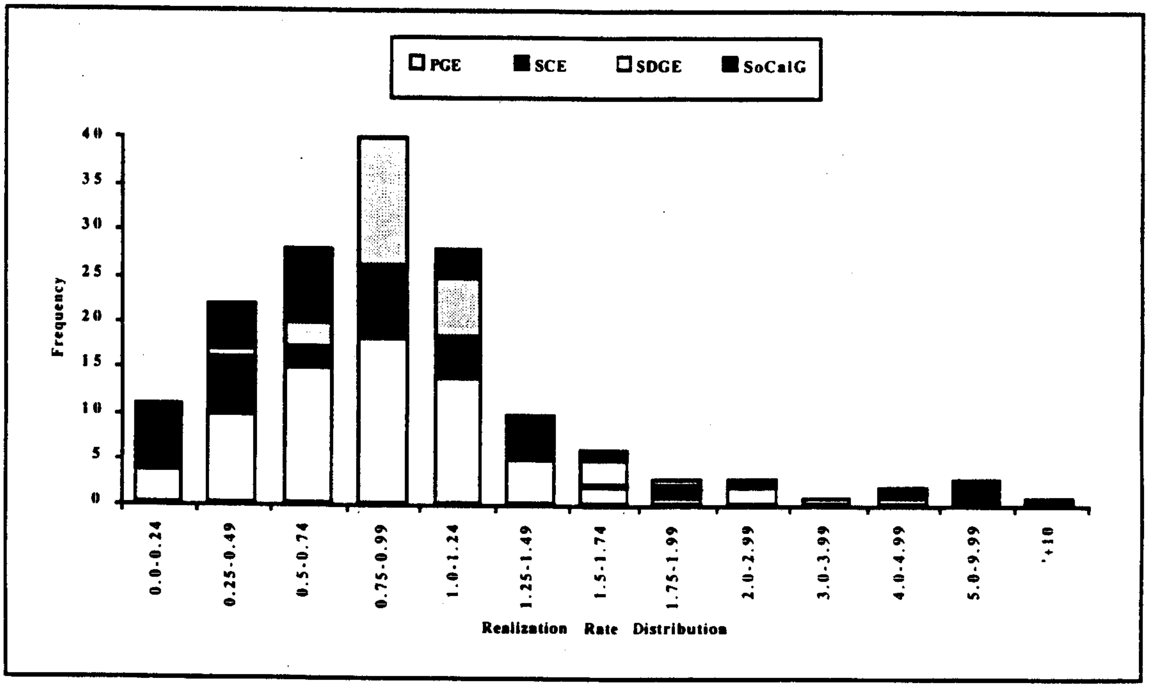


Figure 5.1 Distribution of Realization Rates (N=158)

SoCalG and SDG&E have the lowest median values for their realization rates (with 0.66 and 0.68, respectively). SCE has the highest median value (0.87), and PG&E's median realization rate is almost as high at 0.82.

[2] The median value is an unweighted measures of central tendency. Each realization rate is given an equal weighting in its calculation, even though one value may represent a large program and may cover multiple years of program operation while another realization rate may represent a component of a smaller program and only a single year of operation. It was not possible to weight the realization rates by expenditure levels because the cost data listed in each utility's annual DSM report often did not correspond to the specific program segments covered by the realization rates.

5.2 REALIZATION RATES BY SECTOR AND PROGRAM TYPE

The realization rates for nonresidential DSM programs tend to be higher than those for residential DSM programs (Table 5.2). The median value for nonresidential DSM programs is 0.91, while the median realization rate for residential programs is 0.69.

Table 5.2 Median Realization Rates by Sector

Sector:	Median Value of Realization Rates	Number of Programs or Program Segments
Residential	0.69	52
Nonresidential	0.91	65

The nonresidential programs also account for the five highest realization rates (Figures 5.2 and 5.3). All of these are associated with programs operated by SoCalG and four of them relate to commercial programs. They include:

- the High Efficiency Commercial Equipment Program (boilers, dryers, and weatherization),
- the Industrial Equipment Replacement Program (space heat), and
- the High Efficiency New Commercial Building Program (water heating).

The nonresidential programs also have a cluster of low realization rates ranging from 0.1 to 0.3. As with the high rates noted above, these low rates are also associated with programs operated by SoCalG, but they are dominated by industrial programs. They are:

- the Industrial Equipment Replacement Program (boilers, dryers, and furnaces),
- the Industrial Heat Recovery Program, and
- the High Efficiency New Commercial Building Program (space heat and cooking).

In contrast to the nonresidential programs, none of the realization rates for residential programs exceed 3.8. The two highest rates are associated with PG&E programs:

- the Ceiling Insulation Rebate Program (demand component) and
- the Residential Energy Savings Program (wraps for electric domestic hot water heaters).

In addition to the two extremely low values noted earlier for PG&E's Energy Saver Showerhead Coupon Program, eight additional residential programs or program segments have realization rates of 0.3 or less. All but one of these are associated with residential direct assistance programs:

- PG&E's Energy Partners Program (gas-heated single-family dwellings with air conditioning)
- PG&E's Energy Partners Program (gas-heated single-family dwellings without air conditioning)
- SCE's Customer Assistance Program (weatherization)
- SCE's Customer Assistance Program (evaporative coolers and heat pumps)
- SoCalG's Weatherization/Conservation Program (attic insulation)
- SoCalG's Weatherization/Conservation Program (water-heater blanket)
- SoCalG's Weatherization/Conservation Program (low-flow showerhead)

The other low realization rate pertains to the low-flow showerheads installed by PG&E's Residential Energy Savings Program in dwellings with gas water heaters. Altogether, four of the lowest ten residential realization rates are associated with low-flow showerheads.

Of the seven types of DSM programs shown in Table 5.3, the lowest realization rates are experienced by residential direct assistance programs (with a median value of 0.53). Recall that these programs account for a large share (29%) of the total DSM expenditures of the four utilities during the three-year study period. The median realization rate for residential energy management services programs is also low, at 0.59. Both of these types of programs earn performance-adder incentives for the utilities, and not shared savings incentives.

Figure 5.2: Realization Rates for All Residential Programs

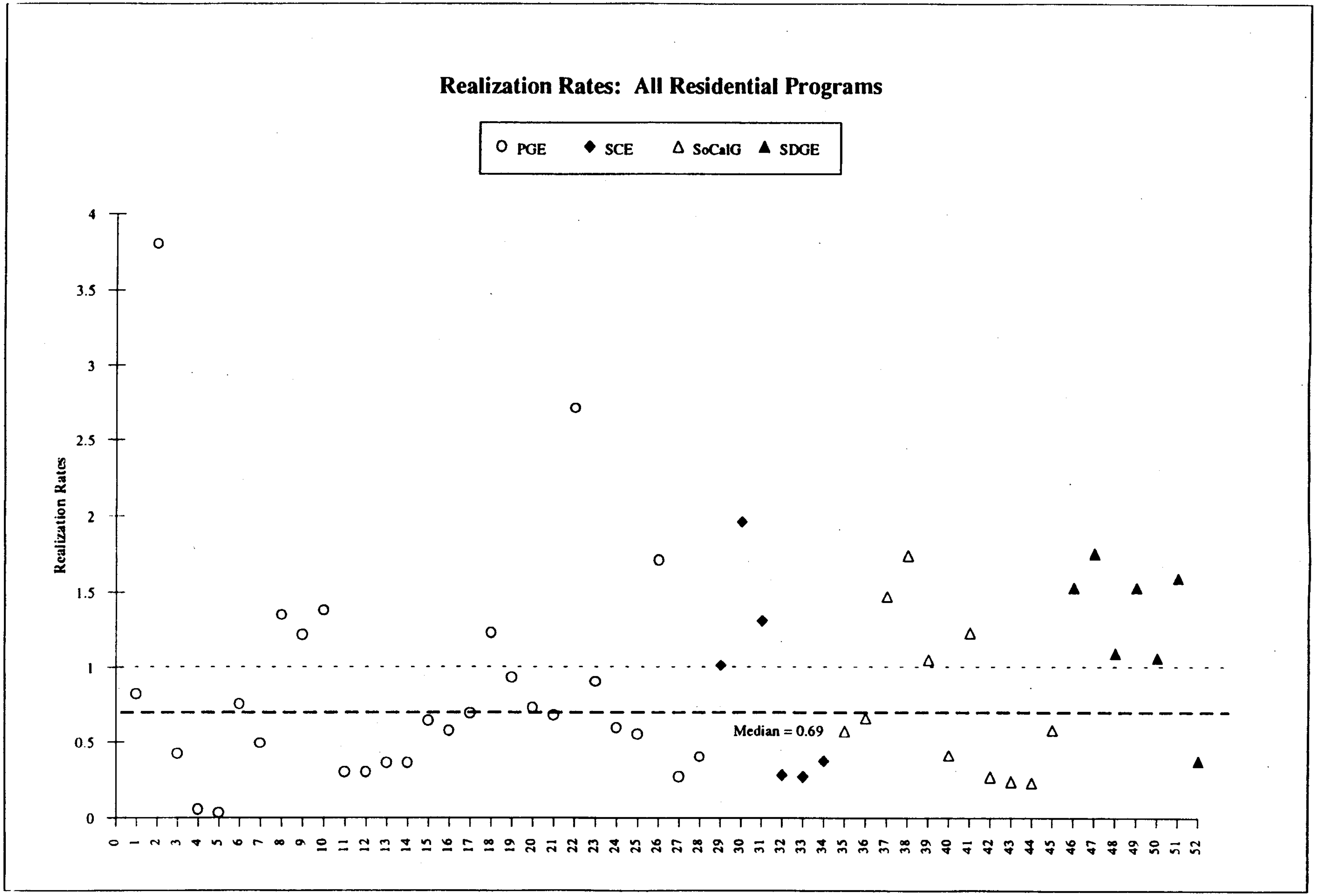


Figure 5.2: Realization Rates for All Residential Programs

Obs.	Rpt#	Period	Program Name	Coverage	Obs.	Rpt#	Period	Program Name	Coverage
1.)	12A	1991-92	Ceiling Insulation Rebate	Elec. Energy Savings	28.)	26G	1991	Res. Energy Savings	Indirect savings-gas
2.)	12B	1991-92	Ceiling Insulation Rebate	Capacity Savings	29.)	64A	1990-92	Res. Appliance Efficiency Incen.	Air conditioners
3.)	12C	1991-92	Ceiling Insulation Rebate	Gas Savings	30.)	64B	1990-92	Res. Appliance Efficiency Incen.	Refrigerators
4.)	13A	1992	E. Saver Showerhead Coupon	Gas	31.)	66	1990	Res. Energy Mgmt. Svc.	
5.)	13B	1992	E. Saver Showerhead Coupon	Elec.	32.)	68A	1990-91	CAP: Weatherization	Refrigerator replacements
6.)	14	1992	Res. CFLB	CFLB	33.)	68B	1990-91	CAP: Hardware	E.-Eff Hdwr Install/Evap Coo
7.)	22A	1991	Energy Partners	SF w/ AC-elec	34.)	68C	1990-91	CAP: Relamping	Relamping
8.)	22B	1991	Energy Partners	SF w/o AC-elec	35.)	129A	1990-92	Res. Weatherization	Water Heater Wrap
9.)	22C	1991	Energy Partners	MF w/ AC-elec	36.)	129B	1990-92	Appliance Efficiency	High-efficiency DHW
10.)	22D	1991	Energy Partners	MF w/o AC-elec	37.)	129C	1990-92	Appliance Efficiency	High-efficiency space heaters
11.)	22E	1991	Energy Partners	SF w/ AC-gas	38.)	130A	1990-92	Appliance Repair & Replace	Furnaces
12.)	22F	1991	Energy Partners	SF w/o AC-gas	39.)	130B	1990-92	Appliance Repair & Replace.	Water heaters
13.)	22G	1991	Energy Partners	MF w/ AC-gas	40.)	130C	1990-92	Appliance Repair & Replace	Ranges
14.)	22H	1991	Energy Partners	MF w/o AC-gas	41.)	130I	1990-92	Appliance Repair & Replace	-wide statistics
15.)	24A	1991-92	Targeted Customer Appliance	1991 electric (MWh)	42.)	130D	1990-92	Weatherization/Conservation	Attic insulation
16.)	24B	1991-92	Targeted Customer Appliance	1992 electric (MWh)	43.)	130F	1990-92	Weatherization/Conservation	DHW blanket
17.)	24C	1991-92	Targeted Customer Appliance	1991 gas	44.)	130G	1990-92	Weatherization/Conservation	LF showerhead
18.)	24D	1991-92	Targeted Customer Appliance	1992 gas	45.)	195	1990	Res. EMS	
19.)	24E	1991	Targeted Customer Appliance	Refrig. replacements	46.)	144	1991	Central AC Program	
20.)	24F	1991	Targeted Customer Appliance	Refrig. replacements	47.)	149	1991	Low-Flow Showerhead	
21.)	24G	1991-92	Targeted Customer Appliance	CFLB	48.)	150	1991	Res. CFLB	
22.)	26A	1991	Res. Energy Savings	DHW wraps-elec	49.)	152	1991	Res. High Efficiency Refrig.	
23.)	26B	1991	Res. Energy Savings	CFLB-electric	50.)	155	1990-91	Ap Ef. Incentives: Low-Flow S.	
24.)	26C	1991	Res. Energy Savings	LF showerhead-elec	51.)	156	1992	Ap Ef. Incentives: CFLB	
25.)	26D	1991	Res. Energy Savings	Indirect savings-elec	52.)	158	1992	Res. Direct Assistance	
26.)	26E	1991	Res. Energy Savings	DHW wraps-gas					
27.)	26F	1991	Res. Energy Savings	LF showerhead-gas					

Figure 5.3: Realization Rates for All C/I A Programs

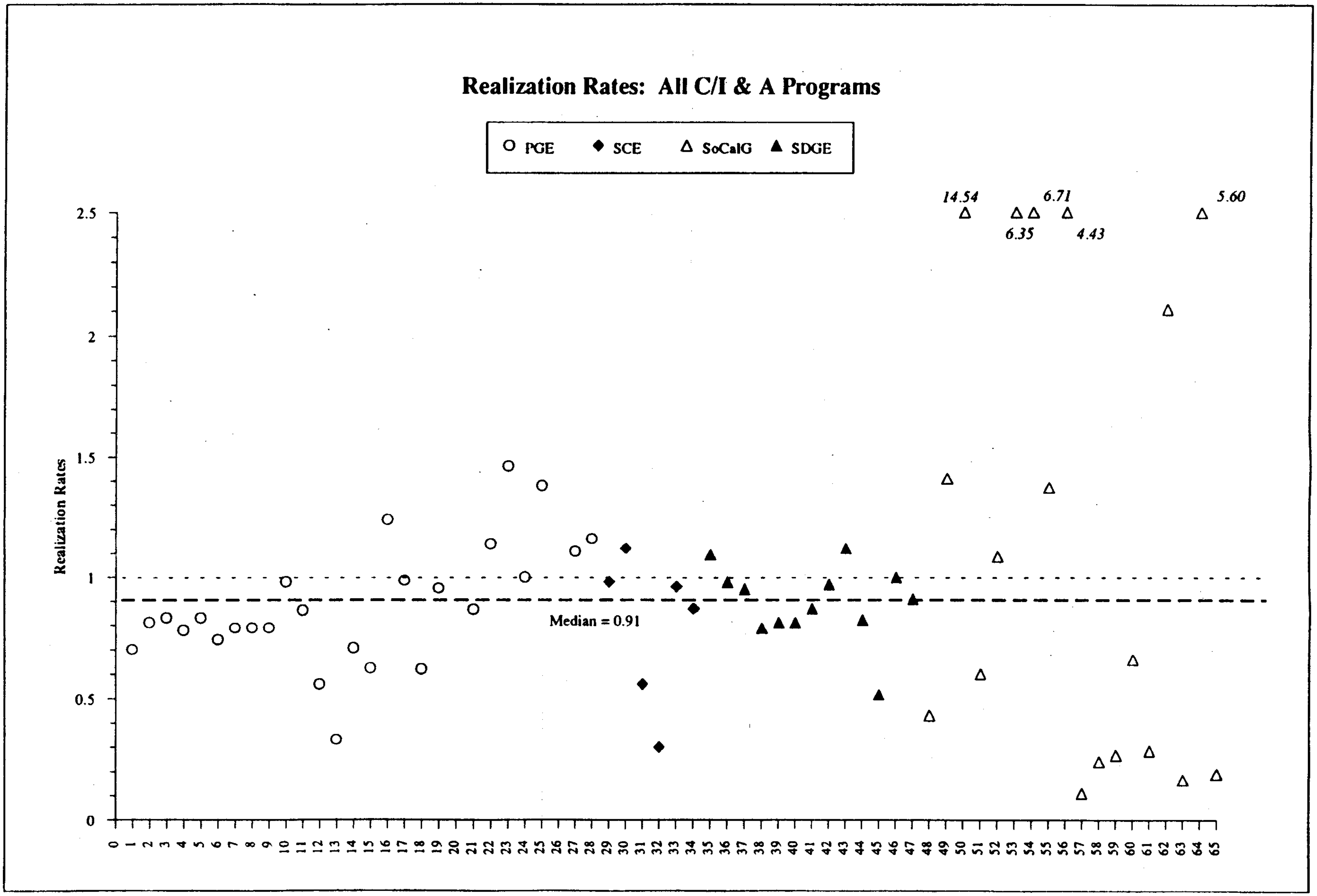


Figure 5.3: Realization Rates for All C/I A Programs

Obs.	Rpt#	Period	Program Name	Coverage	Obs.	Rpt#	Period	Program Name	Coverage
1.)	43	1991 - 1992	C/I & Agri. Retrofit Rebate	Agricultural (Gross)	34.)	87O	1990	C/I & Agri. EMS & HDWR Rebate	Indoor Lamps
2.)	43	1991 - 1992	C/I & Agri. Retrofit Rebate	Commercial (Gross)	35.)	N/A	1991	Agricultural EMS	Agricultrual EMS (Therms)
3.)	43	1991 - 1992	C/I & Agri. Retrofit Rebate		36.)	162	1985-1989	Non-Residential Audit Evaluation	kW (Total)
4.)	43	1991 - 1992	C/I & Agri. Retrofit Rebate	Gross Savings (Total)	37.)	0	1985-1989	Non-Residential Audit Evaluation	Therms (Total)
5.)	43	1991 - 1992	C/I & Agri. Retrofit Rebate	Net Savings (Total)	38.)	162A	1985-1989	Non-Residential Audit Evaluation	Space Cooling (kWh)
6.)	43	1991 - 1992	C/I & Agri. Retrofit Rebate	Net Demand Savings (Total	39.)	162B	1985-1989	Non-Residential Audit Evaluation	Space Heating (kWh)
7.)	43	1991 - 1992	C/I & Agri. Retrofit Rebate	Industrial (Gross)	40.)	162B	1985-1989	Non-Residential Audit Evaluation	Space Heating (kW)
8.)	43A	1991 - 1992	C/I & Agri. Retrofit Rebate	Agricultural (Net)	41.)	162C	1985-1989	Non-Residential Audit Evaluation	Lighting (kWh)
9.)_	43A	1991 - 1992	C/I & Agri. Retrofit Rebate	Agricultural (Net Demand)	42.)	162C	1985-1989	Non-Residential Audit Evaluation	Lighting (kW)
10.)	43B	1991 - 1992	C/I & Agri. Retrofit Rebate	Lighting (Net)	43.)	162D	1985-1989	Non-Residential Audit Evaluation	Motor Load (kW)
11.)	43B	1991 - 1992	C/I & Agri. Retrofit Rebate	Lighting (Net Demand)	44.)	165A	11/90 - 8/91	C/I Lighting Retrofit	Ballast: Hybrid
12.)	43C	1991 - 1992	C/I & Agri. Retrofit Rebate	HVAC (Net)	45.)	165C	11/90 - 8/91	C/I Lighting Retrofit	Ballast: T-8 Electronic
13.)	43C	1991 - 1992	C/I & Agri. Retrofit Rebate	HVAC (Net Demand)	46.)	165E	11/90 - 8/91	C/I Lighting Retrofit	Lamp: F32
14.)	44	1990 - 1991	Non-Residential New Construction	KWH	47.)	165H	11/90 - 8/91	C/I Lighting Retrofit	Delamp 2 + Opt. Reflectors
15.)	44	1990 - 1991	Non-Residential New Construction	KW	48.)	137A	1990 - 1992	High Efficiency Commercial Equipment	Cooking
16.)	48A	1990 - 1992	Non-Residential EMS	Commercial	49.)	137B	1990 - 1992	High Efficiency Commercial Equipment	Space Heat
17.)	48A	1990 - 1992	Non-Residential EMS	Commercial	50.)	137C	1990 - 1992	High Efficiency Commercial Equipment	Bolier
18.)	48A	1990 - 1992	Non-Residential EMS	Commercial	51.)	137D	1990 - 1992	High Efficiency Commercial Equipment	Air Conditioner
19.)	179	1990 - 1991	Customized Rebate	Agricultural	52.)	137E	1990 - 1992	High Efficiency Commercial Equipment	Water Heater
20.)	179	1990 - 1991	Customized Rebate	Agricultural	53.)	137F	1990 - 1992	High Efficiency Commercial Equipment	Dryer
21.)	179	1990 - 1991	Customized Rebate	Agricultural	54.)	137G	1990 - 1992	High Efficiency Commercial Equipment	Weatherization
22.)	179	1990 - 1991	Customized Rebate	Commercial	55.)	137H	1990 - 1992	Commercial Energy Efficiency Analyses	Audits
23.)	179	1990 - 1991	Customized Rebate	Commercial	56.)	139A	1990 - 1992	Industrial Equipment Replacemant	Space Heat
24.)	179	1990 - 1991	Customized Rebate	Commercial	57.)	139B	1990 - 1992	Industrial Equipment Replacemant	Boiler
25.)	179A	1990 - 1991	Customized Rebate	Lighting, sample (n=73)	58.)	139C	1990 - 1992	Industrial Equipment Replacemant	Dryer
26.)	179B	1990 - 1991	Customized Rebate	Refrigeration, sample (n=7:	59.)	139D	1990 - 1992	Industrial Equipment Replacemant	Furnace
27.)	179C	1990 - 1991	Customized Rebate	Miscellaneous, sample (n=7	60.)	139E	1990 - 1992	Industrial Equipment Replacemant	Process Cooking
28.)	179C	1990 - 1991	Customized Rebate	Miscellaneous, sample (n=7	61.)	139F	1990 - 1992	Industrial Heat Recovery	Not Applicable
29.)	87A	1990	C/I & Agri. EMS & HDWR Rebate	Packaged A/C	62.)	139G	1990 - 1992	Industrial Audit	Not Applicable
30.)	87B	1990	C/I & Agri. EMS & HDWR Rebate	HVAC EMS	63.)	140A	1990 - 1992	High Efficiency New Commercial Building	Space Heat
31.)	87C	1990	C/I & Agri. EMS & HDWR Rebate	Clock Thermostat	64.)	140B	1990 - 1992	High Efficiency New Commercial Building	Water Heating
32.)	87D	1990	C/I & Agri. EMS & HDWR Rebate	Indoor Lighting System	65.)	140C	1990 - 1992	High Efficiency New Commercial Building	Cooking
33.)	87M	1990	C/I & Agri. EMS & HDWR Rebate	Grouped Process Hardware					

Actual Realization rates are [illegible]

Table 5.3 Median Realization Rates by Type of Program

Type of Program:	Median Value of Realization Rates	Number of Programs or Program Segments
Residential retrofit incentives	1.06	17
Nonresidential retrofit incentives	0.91	52
Residential direct assistance	0.53	26
Residential new construction	0.70	8
Nonresidential new construction	0.66	6
Residential energy mgmt. services	0.59	9
Nonresidential energy mgmt. services	0.95	40

Residential retrofit incentive programs have the highest median realization rate (1.06), while nonresidential retrofit incentive programs have a median realization rate that is similar to the median value for all seven types of DSM activities (0.91 compared to 0.87 for all). Recall that retrofit incentive programs (residential and nonresidential) account for the second largest share of total DSM expenditures (23%) during the three-year study period. Nonresidential energy management services programs have a median realization rate of 0.95, indicating that they generated 95% of the energy savings they were projected to deliver.

5.3 REALIZATION RATES PRODUCED BY DIFFERENT EVALUATION METHODS

Realization rates are influenced by numerous factors. First, external events such as economic conditions within a utility's service territory may cause a program to generate more or less energy than planned. Economic growth, for instance, may increase the hours of operation of a commercial or industrial establishment, thereby increasing the energy saved by the installation of energy-efficient equipment. Alternatively, increasing demand for an energy-efficient product may increase the free riders served by a program, thereby decreasing the energy saved by the program.

Second, and most germane to this section, is the impact of measurement and analysis techniques on the estimation of realization rates. Methods of estimating *ex-ante* and *ex-post* energy savings may introduce biases in the estimation of realization rates. For instance, simple engineering calculations of *ex-ante* energy savings have historically overestimated the actual energy savings generated by DSM programs (Keating, 1991). It was not possible to characterize the type of method used to produce *ex-ante* estimates of energy savings. However, we were able to examine the evaluation method used to generate *ex-post* estimates of energy savings. In this section, a typology of seven evaluation methods is used to examine median realization rates. In Section 5.4 we look more closely at evaluation methods in conjunction with three selected DSM measures.

Tables 5.4 and 5.5 present the median realization rates for the seven evaluation methods, and for residential and nonresidential programs, separately.

Table 5.4 Realization Rates for Seven Evaluation Methods

	Residential Programs		Nonresidential Programs	
Evaluation Method:	**Median Value of Realization Rates**	**Number of Programs or Program Segments**	**Median Value of Realization Rates**	**Number of Programs or Program Segments**
Billing analysis	0.64	23	0.86	33
Conditional demand analysis	0.68	20	1.09	14
Metered data	1.01	3	NA	NA
Simplified engineering model	NA	NA	1.00	26
Engineering simulation model	0.48	6	0.78	6
Statistically adjusted engineering approach	0.69	13	0.87	20
Calibrated engineering model	1.31	6	0.79	13

* Total exceeds 158 observations due to multiple methodologies being applied in some cases.

The billing analysis, engineering simulation model, and the statistically adjusted engineering approach evaluation methodologies all produce similar results in that realization rates of less than one are observed for both residential and nonresidential programs. The tendency for billing analysis to produce lower-than-average realization rates is highlighted by the fact that it accounts for four of the six lowest nonresidential realization (all four of which relate to industrial programs). In the residential sector, the low median realization rate reflects the fact that billing analysis appears to be the "methodology of choice" for evaluating residential direct assistance programs, and these equity programs tend to deliver significantly less than their *ex-ante* estimated savings.

Of the remaining evaluation methods, calibrated engineering models produce a high median realization rate in the residential sector, and a low median value in the nonresidential sector. In contrast, conditional demand analysis produces a high median realization rate in the nonresidential sector with a lower median observed in the residential sector. Simplified engineering models produce a median realization rate of 1.00 in the nonresidential sector, and were not used at all in the residential sector.

5.4 REALIZATION RATES FOR SELECTED MEASURES

Realization rates for three DSM measures are examined in this section: compact fluorescent lamps, low-flow showerheads, and refrigerator replacements. Collectively, these three measures have median realization rates that span the spectrum from 0.27 for low-flow showerheads to 1.23 for refrigerator replacements, and also include one measure with an average median realization rate (0.83 for compact fluorescent lamps) (Table 5.5). In addition to the wide variation in realization rates across programs offering different measures, there is also considerable variation in realization rates across programs offering similar measures. Features of the DSM programs that offer these measures and their impact evaluations are described below in an attempt to explain why realization rates are so variable.

Table 5.5 Median Realization Rates by Selected Measure

	Median Value of Realization Rates	Number of Programs or Program Segments
Compact fluorescent lamps	0.83	6
Low-flow showerheads	0.27	7
Refrigerator replacements	1.23	4

The impact evaluations present six realization rates for compact fluorescents. These rates vary from 0.37 to 1.59, and have a median value of 0.83. Table 5.6 summarizes some of the key features of these programs and their impact evaluations.

Table 5.6 Analysis of Realization Rates for Compact Fluorescent Lamps

	#68C	#24G	#14	#26B	#150	#156
Realization Rate	0.37	0.68	0.75	0.90	1.09	1.59
Ex-Ante Net Savings (kWh/bulb)	89	71	77	142	51	32
Ex-Post Net Savings (kWh/bulb)	33	48	58	128	56	51
Lamps Per Part.	4.6	1.0	2.8	2.0	1.5	1.9
Utility	SCE	PG&E	PG&E	PG&E	SDG&E	SDG&E
Evaluation Method[a]	SAE	SAE	CEM	BA	CEM	CEM
Rebound Est.	No	No	Yes	No	No	No
Free Riders Est.	No	Yes	Yes	Yes	No	No

[a] SAE=statistically adjusted engineering approach
CEM=calibrated engineering model
BA=billing analysis

The six programs varied significantly in the assumed (*ex-ante*) energy savings of a compact fluorescent bulb, ranging from 32 to 142 kWh/lamp. Uniformity is not to be expected, since energy savings depend upon hours of use, replaced wattages, and levels of free ridership, among other variables. However, the rationale for why the SDG&E program should be expected to deliver only one-fourth to one-third the savings per bulb of the PG&E Residential Energy Savers Program is unclear. In any event, the low *ex-ante* estimates for the two SDG&E programs partially explain their high realization rates.

The noteworthy feature of the program with the lowest realization rate and the lowest ex-post energy savings (SCE's Relamping Program--#68C), is the installation of 4.6 lamps per participating low-income participant. This rate of installation may exceed the cost-effective opportunities available in the average participant's home.

Different evaluation methods appear to characterize higher versus lower realization rates. Calibrated engineering models were used for both of the SDG&E programs where *ex-post* estimates exceeded *ex-ante* projections. Statistically adjusted engineering approaches were used to evaluate the two programs with the lowest realization rates.

The impact evaluations present seven realization rates for low-flow showerheads. These rates vary from 0.03 to 1.75, and have a median value of 0.27. Table 5.7 summarizes some of the key features of these programs and their impact evaluations.

Table 5.7 Analysis of Realization Rates for Low-Flow Showerheads

	#13B	#13A	#130G	#26F	#26C	#155	#149
Realization Rate	0.03	0.05	0.23	0.27	0.59	1.06	1.75
Ex-Ante Net Savings per Showerhead	418 kWh	19 therms	57 therms	37 therms	832 kWh	26 therms	12 therms
Ex-Post Net Savings per Showerhead	20 kWh	1 therm	13 therms	10 therms	495 kWh	28 therms	21 therms
Utility	PG&E	PG&E	SoCalG	PG&E	PG&E	SDG&E	SDG&E
Evaluation Method[a]	ESM	ESM	CDA	BA	BA	BA	CEM
Rebound Est.	Yes	Yes				No	No
Measure Retention Est.	Yes	Yes	No	Yes	Yes	No	No
Free Riders Est.	Yes	Yes	No	Yes	Yes	No	No

[a] ESM=engineering simulation model
CDA=conditional demand analysis
BA=billing analysis
CEM=calibrated engineering model

The *ex-ante* estimates of energy savings per low-flow showerhead vary widely, from 418 to 832 kWh/year and from 12 to 57 therms/year. The two programs with realization rates that exceed 1.0 are both associated with relatively low *ex-ante* estimates of savings.

As with compact fluorescent lamps, realization rates appear to vary as a function of features of the impact evaluations. The two highest realization rates resulted from evaluations that did not take into account three phenomena that tend to reduce savings estimates: rebound effects, lack of measure retention, and free riders. In contrast, four of the five lowest realization rates were the result of impact evaluations that significantly discounted savings due to these three phenomena.

The impact evaluations present four realization rates for refrigerator replacements. These rates vary from 0.73 to 1.96, and have a median value of 1.23. Table 5.8 summarizes some of the key features of these programs and their impact evaluations.

Table 5.8 Analysis of Realization Rates for Refrigerator Replacements

	#24F	#24E	#152	#64B
Realization Rate	0.73	0.93	1.53	1.96
Type of Program[a]	ER & RR	ER & RR	EER	EER
Ex-Ante Net Savings (kWh/Refrigerator)	537	422	187	46
Ex-Post Net Savings (kWh/Refrigerator)	392	392	286	90
Utility	PG&E	PG&E	SDG&E	SCE
Evaluation Method[b]	SAE	SAE	CEM	CDA
Rebound Est.	No	No	No	No
Measure Retention Est.	No	No	No	No
Free Riders Est.	Yes	Yes	Yes	Yes

a ER=early retirement
RR=refrigerator repairs
EER=incentives to buy more energy-efficient refrigerators

b SAE=statistically adjusted engineering approach
CDA=conditional demand analysis
CEM=calibrated engineering model

The four realization rates listed in Table 5.8 refer to two different types of programs. The highest *ex-ante* savings estimates and the lowest realization rates are associated with refrigerator repair and early retirement programs. The lowest *ex-ante* savings estimates and the highest realization rates were associated with programs that offer incentives to promote the purchase of more energy-efficient refrigerators. Thus, the *ex-ante* savings of the first type were overestimated, and for the second type they were underestimated.

A variety of different methods were used to evaluate the energy saved by refrigerators. As with the previous DSM measures, statistically adjusted engineering approaches produced lower realization rates than calibrated engineering models. All four evaluations used comparison groups and none measured rebound effects or rates of retention. In this regard the evaluations of this DSM measure were more similar to one another than are the evaluations of either of the other two measures, which were more variable.

In sum, realization rates are generally less than 1.0, but are highly variable. No single program feature or evaluation method dictates a program's realization rate. However, by comparing the realization rates of similar DSM measures, it is possible to identify likely influences. In the residential sector, high realization rates are associated with calibrated engineering models, relatively low *ex-ante* estimates of savings, and evaluations that fail to discount savings for free riders, rebound effects, and imperfect measure retention.

CHAPTER SIX
SUMMARY OF DRA AND CEC REVIEW COMMENTS AND UTILITY RESPONSE

The monitoring and evaluation studies summarized in this report were reviewed by the California Public Utility Commission's Division of Ratepayer Advocacy (DRA) and/or the California Energy Commission (CEC). Reviews were conducted either by DRA consultants and/or CEC staff. Copies of the review comments were submitted to the authors of this report for summarization. In addition, two utilities, Southern California Edison and San Diego Gas and Electric submitted responses to the review comments. Review comments and responses were not received for all of the monitoring and evaluation studies summarized in this report. Table 6.1 summarizes the monitoring and evaluation studies for which review comments were received.

The purpose of this chapter is to summarize the review comments and utility responses, as appropriate. The review comments and utility responses generally fall into 11 categories:

- Interaction of program effects with underlying market conditions,
- Comparison groups,
- Peak demand impacts,
- Sample design issues,
- Error estimates,
- *Ex-ante* estimates,
- Weather normalization,
- Conditional demand analysis,
- Engineering simulation modeling,

- Net to gross analysis, and
- Triangulation.

Each of these categories of comments is summarized in the following sections. Where appropriate, utility responses to these comments are also summarized.

Table 6.1 Summary of Review Comments Received and Utility Responses

Study No.	Utility/Program	DRA Comments	CEC Comments	Utility Response
13	PG&E Res. Showerhead Coupon	√		
14	PG&E Res. Compact Fluorescent	√		
15	PG&E Res. Multifamily Rebate	√		
64/65	PG&E Res. Appliance Incentives	√		
130 A-C	SoCalGas Res. Direct Assistance	√		
130 D-H	SoCalGas Res. Weatherization	√		
155	SDG&E Res. Showerheads	√		√
157	SDG&E Res. EMS	√		√
43	PG&E CIA Retrofit Rebate	√	√	
76	SCE Res. New Construction	√	√	
87	SCE CIA Hardware Rebate	√	√	√
88	SCE CIA Hardware Rebate	√	√	√
92	SCE CIA Hardware Rebate	√	√	√
93/94/95	SCE CIA Hardware Rebate	√	√	√
174	SDG&E Comm Lighting Retrofit	√	√	√

6.1 INTERACTION OF PROGRAM EFFECTS AND UNDERLYING MARKET CONDITIONS

Several reviews of the utility monitoring and evaluation studies expressed the concern that appropriate steps were not taken to isolate the impacts of utility DSM programs from underlying market conditions and trends. For example, reviewers noted that some evaluations failed to account for the change in the stock of energy using equipment over time. In addition, building and appliance efficiency standards have been implemented, and in some cases evaluations did not account for these effects. Reviewers pointed out that many of the evaluations did not employ an effective comparison group approach to account and control for these effects in the impact evaluations (see section 6.2).

One utility response (Southern California Edison) pointed out that comparison groups were not necessarily required for effective impact evaluation, and that in some cases comparison groups would be extremely costly to construct since the necessary data for such groups did not exist. This utility noted that it employed a time trend variable in its regression framework which would effectively account for changes in underlying conditions.

6.2 COMPARISON GROUPS

Related to the above discussion, many reviewers noted that selected evaluation studies failed to employ a comparison group. Further, some reviewers pointed out that even in cases where a comparison group was used, its construction may have been flawed. One reviewer asserted that it may not be appropriate to select comparison groups from the same utility service territory where the programs were operational, and that the appropriate comparison should be with comparison groups where no program was available or offered.

Southern California Edison, in its response to reviewer comments, pointed out that this criticism raised significant issues about the whole concept of comparison groups and net to gross analysis. This utility pointed out that its approach to this problem was indeed workable, and if the reviewer comments were to be believed, then the problem was essentially intractable (see section 6.10).

6.3 PEAK DEMAND IMPACTS

Some reviewers pointed out that several measurement and evaluation studies failed to estimate peak demand impacts for the DSM programs and only concentrated on energy impacts. These comments were predominately associated with the evaluations of residential programs, where very few of the evaluations estimated peak demand (kW) impacts.

6.4 SAMPLE DESIGN ISSUES

Several of the reviews critiqued the sample design approaches employed in the evaluation studies. In some cases, reviewers commented that the sample designs were not adequately documented and that details concerning sample stratification were not presented. As a result, reviewers in some cases questioned the representativeness of the impact results and the weighting of impact results in so far as they extended to the participant populations from which the samples were drawn.

Some reviewers believed that the sampling strategies employed in selected evaluations may have introduced bias into the impact estimates, in so far as the samples may have overly represented some participant classes (e.g. large customers). In at least one case, statistical inference issues were mentioned as a concern, since the reviewer pointed out that the population from which the sample was drawn was not the same as the participant population, but rather reflected a sample of customers selected for another purpose (i.e., forecasting).

In several cases, concern was expressed about small sample sizes, which would in turn affect the precision of impact estimates. It was felt that in some cases, samples for certain measures or building types may have been too small to allow for precise enough estimates of impacts.

6.5 ERRORS OF IMPACT ESTIMATION

Related in part to the sampling issue, certain reviewers expressed concern that standard errors for the impact estimates were not consistently reported. In some cases, the errors associated with impact estimates were considered to be too large. Comments were also expressed concerning confidence levels or confidence intervals associated with the standard errors. The assertion was made that confidence intervals in certain cases were too wide. One reviewer expressed the position that the precision associated with the various impact estimates were not sufficiently tight to be used in making decisions concerning incentive earnings associated with the DSM programs.

Southern California Edison pointed out, in its response to comments, that its analyses did not report confidence intervals, but rather confidence levels which were to be interpreted differently.

6.6 EX-ANTE ESTIMATES

A number of reviews asserted the need for reexamination of how *ex-ante* estimates were calculated. It was pointed out that the evaluation studies in question contained too little detail on the calculation of *ex-ante* estimates, which tended to cloud interpretation of realization rates. It was suggested that, based on the results of the *ex-post* analyses, perhaps the *ex-ante* impacts should be recalculated downward, and that the methods used in calculating *ex-ante* estimates should be redefined.

6.7 WEATHER NORMALIZATION

Several reviewers indicated that some evaluations suffered because they did not include long run weather normalization to control for the varying effects of weather. In cases where weather normalization was performed, it was asserted this was only done for the period of one or two years covered by the evaluation, and was not based on long run weather conditions.

One utility pointed out that, in its experience, such long run weather normalization did not add appreciably to the accuracy of the statistical results, and that further, the weather term in the statistical models appeared to be statistically insignificant.

6.8 CONDITIONAL DEMAND ANALYSIS ISSUES

Conditional demand analysis (CDA) was a methodological approach used in many of the evaluations. A wide range of comments were made concerning the specification and use of the CDA framework in the evaluations.

Several reviewers discussed the possible impact of omitted or unobserved variables in the CDA formulation. The essence of these comments was that such unobserved variables could have significant influence on the impact results. For example, terms to explicitly estimate the interaction between HVAC and lighting, for example, were typically not included, and the regressions, in many cases were based on single measures.

In some cases, reviewers questioned model assumptions with respect to implicit assumptions that no changes in operating hours or lighting intensity occurred between the pre-retrofit and post-retrofit periods. These reviewers asserted that assumptions of this type were perhaps unreasonable since operating hours or lighting intensities could change after retrofit based on the presence of more efficient equipment.

Some reviewers expressed the concern that adequate discussion of data editing and quality were missing from the discussion of CDA approaches. These reviewers felt that more detailed discussion of the data preparation aspects of CDA were appropriate in the evaluation studies.

Several reviewers felt that appropriate statistics on the performance of the regressions were lacking in the evaluation studies. Specifically, in some cases it was noted that R-squared statistics and T statistics were not reported.

San Diego Gas and Electric pointed out, in its response to comments, that, in its opinion, R-squared statistics were not all that appropriate, but rather the standard errors of the coefficients were the key to assessing regression performance. San Diego Gas and Electric also pointed out that while colinearity was a problem in the CDA approach, linear combinations of coefficients could be estimated with good precision.

Southern California Edison in its response to comments questioned one reviewer's assertion that a global conditional demand framework, which incorporated all variables of interest could be utilized. Edison rather asserted that customer specific formulations were appropriate, and that any conditional demand framework must, of necessity, incorporate restrictions in the modeling approach, based on modeling feasibility, data availability, and cost effectiveness. Edison also pointed out that there seems to be some semantical issues associated with the terminology of conditional demand analysis. Edison's assertion is that conditional demand analysis is a general term to represent a family of regression based frameworks, and that this was pre-agreed to by both utilities and regulators.

6.9 DOE-2 ENGINEERING SIMULATIONS

Another commonly employed evaluation methodology was engineering simulation modeling employing the DOE-2 computer code. In one specific application of this method, reviewers questioned the sample of buildings which were simulated to reflect impacts of the program. The assertion was made that the sample was overly restrictive, in that it only included five building types, and on a measure basis, very small samples were used.

These reviewers also questioned the validity of the preprocessor routine used in the DOE-2 simulation work to convert on-site survey data to Building Description Language (BDL) needed to drive the simulation code. The reviewers also questioned the approaches used to calibrate the simulation output to billed energy or metered demand, if metering was present in the building. The reviewers asserted that DOE-2 simulation modeling should be subjected to sensitivity analysis on model input assumptions to investigate how savings estimates varied as a function of these input assumptions.

Southern California Edison, in its response to comments, asserted that, in its opinion, DOE-2 represented the most sophisticated engineering simulation tool available, and that it had been well proven in years of application. Further, Edison asserted that an independent test of the preprocessor code validated it in comparison to standard methods for constructing the BDL inputs.

6.10 NET TO GROSS ANALYSIS

A substantial portion of the review comments was devoted to net to gross analysis issues. In come cases, reviewers pointed out that no net savings were estimated and the evaluations solely focused on gross savings estimates. In other cases, reviewers pointed out that the evaluation studies, in their opinion, contained insufficient justification or explanation for the net to gross techniques used in the evaluation.

A substantial portion of the review comments focused on the validity of the discrete choice methodology used in several of the evaluation studies to develop net to gross ratios. One reviewer asserted that it may inappropriate to utilize data from nonparticipants in a utility service territory where the DSM program is being offered as part of the net to gross analysis. Other reviewers expressed general confidence in the discrete choice method, but expressed a concern that more detailed explanation of the survey methods used to provide the data for the net to gross analysis should be provided in the evaluation study. One reviewer suggested an extension of the discrete choice method based on, not only the propensity of a customer to participate in the program, but also on incorporation of the magnitude of expected savings associated with the decision to participate.

Southern California Edison, in its response to comments, defended its approach to estimating net savings and defended the concept of "bi-directional causation". Edison believes that this concept reflects the fact that customers with a high propensity to implement tend to participate in the program. Propensity to implement causes customers to participate in the program, and participation in the program increases the customer's propensity to implement.

6.11 TRIANGULATION RULES

Several reviewers expressed the view that in impact evaluations where triangulation was used, that the rules for weighting or deriving the final impact estimates from the several estimation methods used were not clear. One reviewer questioned how estimates from different methodologies were "integrated". Another reviewer pointed out that in his opinion rules for selecting the final impacts estimates were "post hoc and ad hoc" and that the utility tended to select the estimates which were either most favorable, in terms of savings, or closest to the ex-ante estimates (thus presuming a realization rate of 1.0 in these cases).

Southern California Edison responded to this particular criticism that the speculation that the decision rules appeared to post hoc and ad hoc was unsupported. Edison does agree additional work is necessary to increase the quantitative rigor associated with triangulation decision rules, and recommended future work in this area.

CHAPTER SEVEN
CONCLUSIONS

This report represents an attempt to summarize over 50 individual evaluation studies conducted by the four largest California investor owned utilities. The effort involved the review of extensive amounts of material, including utility annual DSM activities reports, the individual evaluation studies themselves, written reviewer comments on the evaluation studies, and selected utility responses to comments. Based on this review, the authors offer the following conclusions:

- The evaluation studies summarized in this report represented a monumental effort. Vast amounts of data were collected and analyzed and in general, state-of-the-art methodologies were employed in an attempt to quantitatively estimate the energy and demand savings associated with the DSM programs of the four utilities.

- The quantity of demand and energy savings documented in the evaluation studies is substantial. For example, PG&E's Commercial, Industrial, and Agriculture Rebate Program produced in excess of 663,000 megawatt hours over a two year period. According to an analysis by Eric Hirst of Oak Ridge National Laboratory[3] based on Energy Information Administration survey data, three of the four utilities covered in this report were among the top 25 utilities in the nation in terms of the magnitude of energy savings from DSM reported for 1990 (Southern California Edison, Pacific Gas and Electric, and San Diego Gas and Electric). The percent of generation saved by these three utilities in 1990 according to Hirst was 0.8 for Southern California Edison, 0.5 for Pacific Gas and Electric, and 0.6 for San Diego Gas and Electric.

- The transferability of savings estimates from DSM programs across utilities would be a desirable outcome so that utilities could learn from each other's evaluation experience. This might, in the future, obviate the need for

[3] Eric Hirst, *Electric Utility DSM Programs: 1990 Data and Forecasts to 2000*, ORNL/CON 347, Oak Ridge National Laboratory, Oak Ridge, Tennessee, June 1992. The data in Dr. Hirst's report are based on the EIA 861 Survey. They are therefore, presumably *ex-ante* estimates.

individual formal evaluations of every program. However, the transferability of savings estimates was impaired in this study due to the lack of common reporting formats. The utilities employed a wide variety of evaluation methodologies with no consistent structure for reporting results. Particularly in the commercial, industrial, and agricultural studies, the four utilities pursued four entirely different approaches to both the analysis and presentation of impact results. This made the job of consistent summarization and transferability extremely difficult. Future evaluation efforts, if they are to be compared consistently, should adopt common reporting formats.

- The analysis of realization rates indicated a high degree of variability in the *ex-ante* estimates. In some cases for similar technologies and measures, *ex-ante* savings estimates varied by as much as 300%. This often had a strong impact on realization rates. Future evaluations might benefit from more consistent development and utilization of *ex-ante* approaches to narrow the range of variability.

- The objective of evaluation is to enhance program performance. The lessons learned from evaluation may be factored back into program re-design to improve performance, reduce costs, and enhance savings and program efficiency. The wide degree of variation in *ex-post* savings estimates suggests that there are lessons to be learned about program design features that lead to higher or lower savings. In other words, what is it about some programs that make them generate greater savings than other similar programs. The use of highly varying evaluation methods, however, makes it difficult to isolate program design effects. Future efforts may seek to evaluate similar programs using similar methods so as to be able to gain better insight into the program design features which affect the savings.

- For effective use in state-level DSM planning and forecasting, the ability must exist to aggregate savings estimates and evaluation results. The authors feel that the evaluation studies in this summarization report offer valuable information for state-level planning. However, the structure of the studies did not permit consistent aggregation, and extreme caution should be utilized in attempting to totalize savings. The adoption of consistent reporting formats and structures in the future should greatly facilitate the ability to aggregate the savings results.

The objective of this report was to summarize the evaluation studies. Additional analysis and review is recommended to assess particular components of the evaluations. For example, with some additional research, realization rates could be weighted by energy savings or expenditure levels to produce greater insights into appropriate areas for more precise measurement and evaluation.

In summary, the studies reviewed for this report provide a sound basis for a) obtaining insights into the performance of DSM programs, b) development of information which can be used to enhance program performance, and c) future evaluation work. The California monitoring and evaluation protocols should allow future evaluation efforts to build off this base and produce results which allow cross-utility summarization.

APPENDIX A

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BIBLIOGRAPHY

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APPENDIX B

OVERVIEW OF EVALUATION METHODOLOGIES

This appendix provides a brief overview of evaluation methodologies employed to estimate energy and demand impacts in the evaluation studies. Greater detail on the methodological approaches can be found in the following sources, from which this summary was extracted:

Electric Power Research Institute, *Impact Evaluation of Demand Side Management Programs: A Guide to Current Practice*, CU 7179, Volume 1 Final Report, February, 1991

Oak Ridge National Laboratory, *Handbook of Evaluation of Utility DSM Programs*, ORNL/CON-336, December, 1991

The impact evaluation evaluations methods employed in the subject studies can basically be organized into four key categories:

- Engineering methods,
- Statistical methods,
- Metering,
- Hybrid methods.

Each is briefly discussed in the following sections. The reader is referred to the above sources for greater detail.

Engineering Methods. Engineering estimation of savings typically involves equations which express energy use or demand in terms of a usage level divided by an efficiency for some period of time. There may also be terms in the equations that account for interactions with other end-uses or net gains or losses from previous time periods.

In many cases, engineering methods are concerned with unit impacts of a particular measure such as an energy efficient ballast. Data on the number and type of different measures installed by program participants is extracted from the program data base. An engineering analysis is applied to develop reliable estimates of unit impacts. These unit impacts may be derived from engineering simulations or from more simple engineering algorithms.

Simplified engineering algorithms have been developed for many common DSM measures, such as lighting, various types of HVAC, and water heating measures.

Several of the evaluation studies summarized in this report included the use of engineering simulation modeling. The primary value of such models is in estimating savings in HVAC energy use through either HVAC or envelope modifications. The advantage that simulation tools provide is their ability to account for thermal mass effects, scheduling, interactive effects between different end uses, part load efficiencies, and system dynamics. In other words, simulation models may more accurately account for transient effects in the energy use of a building.

There are two general types of engineering simulation models, hourly and bin. Hourly models model every hour of the year in sequence. The bin method, on the other hand, corresponds to a five or ten degree range of ambient temperatures known as temperature bins. A common hourly engineering simulation tool used in the impact evaluations summarized in this report is DOE-2.

In some cases, engineering results for simulation models may be calibrated to some other known measurement, such as billed energy or, if available, metered load data. This calibration provides some assurance that, for example, the sum of the disaggregated end-use loads totals the building load as measured (see section on Hybrid methods).

Engineering models typically rely on engineering judgment for virtually every input. They are applied to units. Engineering algorithms, for example, may be applied to estimate the impacts of individual DSM measures, whereas in the case of building simulation models, the unit is almost always a building. In consequence, the impact evaluation studies summarized in this report often estimate impacts for individual measures or for representative buildings.

Statistical Methods. There are a variety of statistical approaches which are used to estimate impacts of DSM programs. These statistical methods generally fall into two basic categories:

- Comparison approaches using data available in-house at the utility, and

- Multivariate regression approaches using customer specific survey data.

Simple comparison approaches can be significantly less expensive in that they only require billing data and information on when the customer began participating in the DSM program. On a simplified basis, therefore, they can be applied without the need to collect external customer data. Billing analysis is a general catch phrase for these types of simplified approaches, since the data for these analyses is usually available directly from the utility's billing file and the program tracking data base.

Such comparison approaches can be divided further:

- Time series comparison simply compares the participants energy use before the program to their energy use after the program. Any differences are then attributed to the DSM program.

- Cross sectional comparison. This approach compares the participant's post program energy use to the post program energy use of a control group of nonparticipants. Implicit in this approach is the assumption that the nonparticipant control group is identical to the participant group in all respects except for program participation.

- Pre\post comparison. The pre\post comparison approach compares the change in the quantity of energy use over two time periods for two groups, the program participants and a control group of nonparticipants. This approach combines the features of the cross sectional and time series approaches.

These statistical comparison approaches can be augmented through weather normalization, because weather has a large effect on energy use. The effect of such normalization is to remove the influences of weather, both over time and across participant and nonparticipants groups, thus allowing for more clear cut attribution of impacts to the DSM program.

Multivariate Regression. Multivariate regression approaches utilize a fuller data set than the more simple comparison approaches described above. They typically require survey data on individual customers. These multivariate statistical approaches all rely on the basic premise that changes in one variable can be explained by reference to changes in several other variables. In general, a multivariate regression model for an impact evaluation should include all measurable factors which influence energy consumption. The most commonly employed multivariate approach for energy and demand impact analysis involves using conditional demand analysis. Conditional demand frameworks are based on well defined engineering and economic principles. The conditional demand model is based on the identity that total energy consumption must be equal to the consumption of all of the energy consuming equipment in the building. There are many formulations of conditional demand models which can incorporate different levels of complexity. These models rely on external data collection, in that energy using equipment in the building must be known and incorporated in the model as well as billing data. Many of the DSM impact evaluation studies summarized in this report utilized the conditional demand analysis framework for estimating impacts.

Metering Approaches. A straight forward way of measuring the impact of a particular device is to instrument the device and collect its electricity consumption over selected time intervals. This is known in the utility industry as load research. Direct load research measures class or end-use demand (kW), energy (kWh), or reactive power (kVAR).

Implementing metering as part of any study involves several interrelated steps. These include:

- Sample design,
- Sample selection,
- Recorder selection,
- Meter placement and replacement,
- Installation record keeping,
- Meter operation and maintenance,
- Data collection,

- Data validation and editing,
- Data analysis.

Metering is therefore highly expensive. The hardware must be acquired, and must be installed by trained personnel. Metering at the end-use level often requires the use of qualified electricians and the infrastructure must be in place to collect and analyze massive amounts of data.

Because of its extensive cost, metering is not frequently used in DSM evaluation, though it is often used in support of other methodologies. However, such metering represents the most accurate measurement of energy usage since, if properly installed, it represents direct measurement of the phenomenon as opposed to estimated impacts which are derived from engineering or statistical methods.

Metering can be performed at the whole building (premise) level. This involves recording load at the point where the power service enters the building. Metering can also be performed at the end-use level. This involves instrumenting individual end-uses, such as air conditioners, refrigerators, lighting circuits, etc.

Hybrid Approaches. In some cases hybrid approaches involving combinations of engineering, statistical, and metering methods are employed in DSM program impact evaluation. These hybrid approaches often seek to improve the quality and accuracy of the estimates available from any single approach. Another key objective of such hybrid approaches is to leverage the accuracy of high cost measurement approaches such as metering by combining them in small number with more general approaches.

An example of this type of approach is statistically adjusted engineering (SAE) estimates. SAE uses engineering estimates of savings as independent variables directly in a statistical model. An alternative use of the method is to disaggregate whole house or building metered loads into individual end-uses. Statistically adjusted engineering estimates are generated by using engineering estimates as independent variables in a regression equation instead of zero-one participation variables. This has the effect of combining an initial estimate of the savings of a particular measure with the statistically estimated savings so as to improve the overall precision of the statistical methods. This therefore, brings more information to bear on the estimation problem.

Another hybrid method which has recently evolved in the literature is the employment of double ratio estimation, which is based on the enhanced theoretical statistical performance of ratio estimators. In this approach, double sampling is typically employed, whereby a small sample of higher cost but presumably more accurate measurement (such as that derived from metering) is combined with a larger sample of lower cost data such as that available from a customer survey or billing information. The approach then seeks to analyze the ratios of the different estimates to produce an estimate of the impact of the DSM measure or program with increased precision. It should be noted that such methods were not typically employed (with one exception) in the evaluation studies reviewed as part of this report as they have only been developed in the literature in recent years.

Net to Gross Methods. Net to gross methods are those techniques used to adjust impact estimates on a gross level to account for freeriders. Freeriders are defined as customers who would have taken the identical action without the DSM program. There are also incremental freeriders and deferred freeriders, who may have been to some extent influenced by the program.

Several methods to estimate freeridership, and thus adjust gross savings to reflect net savings, have been employed. Survey based approaches have frequently been used to measure freeriders. Participants are surveyed and are asked several questions concerning what actions they may have taken if the program was not available. Based on the results of these surveys, proportions are estimated based on the respondents reporting of actions which would have been taken, and savings are adjusted accordingly based on these proportions. Survey based approaches to freeridership estimation have been known to have problems associated with self-reporting, particularly when such surveys are administered months or even years after the participant's decision to participate in the DSM program.

In some cases, market data is used to estimate freeridership. For example, data available from appliance dealers on general sales trends may be used to develop estimates of the underlying market in terms of the rated energy efficiency of products being sold, or dealer surveys may be employed in this context to determine what customers are purchasing in general without the existence of a particular incentive program.

The use of a comparison group is also a typical evaluation technique to account for freeridership. The difference between the energy conservation actions of a sample of program participants and an appropriately selected comparison group provides an estimate of the net program impacts. However, this approach is made difficult by the challenge of finding a comparable comparison group that has not already been "contaminated" by knowledge of the existence of the program.

Statistical methods have also been used to estimate freeridership. Generally this method involves analysis of the energy related actions, characteristics, and attitudes for samples of participants and nonparticipants. Simulations are developed to predict the likelihood of the adoption of program sponsored measures with and without the program. The two estimates are then used to calculate the freerider ratio. A particular multivariate modeling approach is the discrete choice model. It uses discrete outcomes as a dependent variable. The dependent variable is 1 if the customer is a participant and 0 if the customer is a nonparticipant. Independent variables include the factors that influence customer decisions to participate in the DSM program including: income, expected energy savings resulting from participation, and awareness of the program.

The DSM studies summarized in this report utilized several of these techniques to adjust gross estimates of savings for freeridership.