FINAL REPORT

Scoping Study of Efficient Refrigerator Impact Parameters and Evaluation Methods

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Prepared for:

The California DSM Measurement Advisory Committee
Subcommittee on High Efficiency Refrigerator Studies

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SUMMARY

This report presents the results of HBRS's scoping study of efficient refrigerator program impact parameters performed for the California DSM Measurement Advisory Committee (CADMAC). The goal of this study was to review the high-efficiency refrigerator programs conducted by the California utilities, to investigate various issues surrounding their impacts, and to recommend reliable methods for estimating program impact parameters and statewide studies to support these estimates. The project had the following six major tasks:

- Review the existing and planned high-efficiency refrigerator programs conducted by the California utilities and the associated impact projections and evaluation results
- Evaluate the transferability of refrigerator load data and analyses across utilities
- Review the usefulness of refrigerator sales and shipments data for estimating components of the net-to-gross ratio, including free-ridership, free-drivership, and market transformation effects
- Review existing estimates of refrigerator useful life and examine the feasibility of alternative methods for obtaining more reliable estimates
- Review existing evidence on rebound effects in high-efficiency refrigerator programs
- Recommend methods and statewide studies to provide improved estimates of program impact parameters based on the reviews in the earlier tasks

The following summarizes the findings from these tasks and the recommendations for a methodology to estimate program impact parameters and statewide studies to support this recommended approach.

REVIEW OF CURRENT PROGRAMS

The objective of this task was to review the activities of the California utilities surrounding their efficient refrigerator programs. The California investor owned electric utilities promote the sales of high-efficiency refrigerators through various programs, the largest of which offer customer rebates for units that significantly exceed the federal standards. Utilities estimate the impacts of these programs for planning purposes using simple engineering methods that rely on the rated efficiencies, generic refrigerator load curves from general end-use metering studies, and assumed net-to-gross ratios.

The California utilities have conducted various evaluation studies in conjunction with their programs. SCE has performed baseline surveys and conditional demand studies of refrigerator purchases and consumption. SCE is also metering a subsample of high-efficiency refrigerators from the 1991 program as part of its Residential Appliance End-Use Study (RAEUS). PG&E has performed a comprehensive evaluation of its 1991 program involving customer and dealer surveys and analyses of AHAM shipments data. PG&E is also metering a large sample of rebated refrigerators from the 1991 and 1992 programs. SDG&E has performed periodic floor stock inventories in conjunction with its program. It also includes questions about its refrigerator program in its regular appliance survey.

In the future, the utilities are considering changing to manufacturer incentives that will be offered through a consortium of Western utilities. PG&E is planning a recycling program, and SCE has already instituted one. These are aimed at accelerating the removal of operating second refrigerators. The issues of free-ridership and free-drivership and effective useful life of refrigerators will continue to be important in these programs as in past ones.

TRANSFERABILITY OF LOAD DATA

The objectives of this task were (1) to investigate the reliability of estimates of refrigerator annual consumption from the Department of Energy (DOE) test procedures as the basis for estimating the adjusted gross program energy savings and (2) to review the applicability of load curves from general end-use metering studies to estimate the gross load impacts of the efficient refrigerator programs. To meet the first objective, HBRS reviewed the results of the one available study performed by a California utility to meter high-efficiency refrigerators. This was the study sponsored by PG&E in 1993. That study found that the difference in average metered consumption between two samples of high efficiency and very high efficiency refrigerators was very close to the average difference based on the estimates from the Department of Energy mandated tests. Based on this finding, we concluded that the DOE based estimates provide a reliable basis for estimating adjusted gross program energy savings.

To meet the second objective, HBRS compared the refrigerator load curves from three different metering studies. The first two studies were the refrigerator portions from PG&E's Appliance Metering Project and SCE's Residential Appliance End-Use Study. These studies metered stratified random samples of the general stock of residential refrigerators. The third refrigerator metering study was the one cited above that was conducted as part of PG&E's evaluation of its 1992 program. The study metered recently installed high-efficiency and very high efficiency refrigerators.

The objective of the comparison was to determine whether there are significant differences in the percentages of annual consumption that refrigerators of various vintages and efficiencies use in each season, day type (weekday versus weekend), and hour. If the percentages do not differ significantly by refrigerator vintage or efficiency, then data from end-use load research studies (performed on samples of the general stock of refrigerators) could be used to estimate the savings by hour from the refrigerator program. The percentages could be calculated from the load research sample. These would serve as reliable estimates of the percentages that the new refrigerators use each hour. They would also provide reliable estimates of the percent of annual savings in critical load periods from increasing efficiencies of these new refrigerators. The calculated percentages from the general load studies could be applied to estimates of annual savings. The annual savings would be computed from the difference in energy estimates for the rebated unit that exceeds the standard and an equivalent unit that just meets the 1993 standard . This is essentially the technique that the California electric utilities currently use to estimate the critical period load savings from their efficient refrigerator programs. An example is provided in the section on transferability of load data to illustrate this.

The comparisons showed that the percentages of use by hour between the studies were generally comparable during the winter months. During the summer months, however, the percentages of use during day time hours by the refrigerators in the general load research studies were lower than those for the new refrigerators from the PG&E program evaluation. At the same time, within the sample of new refrigerators, the percentages did not differ significantly between those that just met the standard and those that exceeded it by 30%. If utilities use their general end-use studies to estimate the percentage of gross savings that are realized during the critical summer periods, they will underestimate them.

REVIEW OF REFRIGERATOR SALES AND SHIPMENTS DATA

The objective of this task was to review the availability and usefulness of information on aggregate refrigerator shipments and sales to estimate various issues surrounding program impacts. These issues include the free-rider and free-driver impacts, as well as possible market transformation effects of the program. The review examined the extent and quality of refrigerator shipments data from AHAM and the availability of sales data from retail dealers. The review found that no single source of sales and/or shipments data would provide all of the information needed to estimate the critical program impact parameters. However, both AHAM shipments and retail sales data from a sample of vendors could be used in combination with a random survey of customers to estimate key program impact parameters, including free-rider and free-driver effects. This approach would require reasonable cooperation rates from major retail chains to be effective.

REVIEW OF REFRIGERATOR USEFUL LIFE ESTIMATES

The objective of this task was to review existing estimates of average refrigerator useful life and the sources of these estimates. The review found that the existing estimates used by California utilities for planning and forecasting are based on "expert judgements" that may have been negotiated as part of various regulatory processes. For example, the value that SCE used in its 1993 DSM program plan was negotiated with the California Public Utilities Commission. Currently, all of the utilities are using values from the DSM Measure Life Project for their DSM program planning. Other estimates of the average life of refrigerators from appliance saturation surveys, refrigerator program evaluations, and refrigerator turn-in programs do not accurately represent the "effective useful life" of refrigerators as defined in the collaborative agreement. The review concluded that a combination of data sources and analyses would be required to accurately estimate refrigerator effective useful life. These include customer surveys to determine the age and disposition of old refrigerators and surveys of businesses and organizations that resell and scrap used refrigerators.

REVIEW OF REBOUND EFFECTS

The objective of this task was to review existing estimates of rebound effects of refrigerator incentive programs and the sources of these estimates. The review found that none of the California utilities include estimates of any rebound response to their refrigerator programs. The review identified only two past studies that have addressed the issue of refrigerator rebound effects. Neither of them found evidence of significant effects on refrigerator capacity, additional features, or retention of second refrigerators. The review concluded that the effects of refrigerator programs on capacity choice and second refrigerator retention could be estimated from survey and sales data.

ESTIMATION OF REFRIGERATOR PROGRAM IMPACTS

Based on the review of the issues under the tasks summarized above, we believe that the *ex-post* first-year impacts of current customer high-efficiency refrigerator rebate programs can be estimated reliably according to the following methods.

Gross Program Energy (kWh) Impacts

The adjusted gross energy[1] (kWh) impacts of the customer rebate programs would be calculated in each utility service territory based on the estimates of annual electricity consumption from the Department of Energy test procedures and the 1993 Federal refrigerator efficiency standards. This is the method that the California utilities currently use to estimate gross energy savings. As part of its program tracking system, each utility would record the estimate of annual consumption for each rebated model reported in the California Energy Commission's listing of federally mandated test results. Each utility would also calculate the 1993 federal standard of maximum allowable annual consumption for the rebated unit based on the formulas in the regulations. The difference between these two numbers would be the estimated savings for each rebated unit. The savings estimate for each unit would be summed over all rebated units in each program year to provide the total adjusted gross energy savings estimate for the program. The adjusted gross savings would also be calculated on the basis of per unit of adjusted volume as required by Table C-3 of the protocols.

This recommendation is based on findings from PG&E's recent high-efficiency refrigerator metering study. That study found that the test results from the Department of Energy procedures provide accurate estimates of the average difference in consumption between refrigerators of different efficiencies. The measured average difference in annualized consumption between a sample of high-efficiency and a sample of very high efficiency refrigerators was very close to the estimated average difference based on the Department of Energy test procedures. The scope of this study and its findings are discussed in detail in the report.

The California utilities could monitor the reliability of the DOE estimates by supplementing their general refrigerator load metering studies with subsamples of high-efficiency units. These samples would be updated regularly to represent the characteristics of recently purchased units. The purpose of this metering subsample would be to confirm whether the estimates based on the federal test procedures continue to provide a reliable basis for determining adjusted gross program savings. The subsamples would be designed so that, in combination with those from the other utilities, they would be reliable at the state level.

[1]The participants in the proceedings that drafted the protocols governing the verification of demand-side management programs in California adopted the convention of defining the "adjusted gross" program impacts as the difference between the energy consumption of efficiency measures that just meet the standards and the consumption of the measures installed under the program.

As an alternative to supplementing their general end-use samples with high-efficiency refrigerators, the California utilities could conduct a special high-efficiency refrigerator metering project periodically. Such a metering study would be performed every five years, or more frequently if CADMAC determined that refrigerator technologies had changed sufficiently to warrant a review of the reliability of the test results. This study would be performed on a sample that is valid at the state level.

Gross Program Demand (kW) Impacts

The demand (kW) impacts of the individual utility programs in each costing period would be estimated by applying inverse load factors to the adjusted gross annual savings estimates. These inverse load factors are simply the ratios of the average or system coincident peak load during a particular costing period divided by the average annual load. For example, the average load during the summer peak period divided by the annual average load would be the ratio used to estimate the average load impacts during that time period. A separate factor--the load coincident with the system peak divided by average annual load--would be used to calculate the gross peak demand impact on the system.

For the 1994 program year, the inverse load factors would be calculated from load data collected from the recent PG&E and SCE metering studies of efficient refrigerators. (The SCE metering project was similar to the one performed by PG&E; however, its results were not available in time for review under this project.) The inverse load factors would be calculated separately for each utility for their respective costing periods and coincident peak conditions. These costing periods include the summer and winter on-peak, off-peak, and partial peak as used by each utility for their system planning, as well as the system peak day. The ratios would be updated periodically based on subsamples of each utility's general appliance metering project or on separate metering studies of high efficiency refrigerators.

Net Program Impacts

The net program impacts would be estimated in each program year by conducting a study of the sales, efficiencies, and characteristics of refrigerators in California and in a comparison area outside of California. This study would rely on information about shipments from AHAM, a survey of refrigerator dealer sales, and a survey of households. The study would be performed at the statewide level with samples sizes to provide reliable results at the service area level. The comparison area would be a region of the United States with demographic characteristics similar to California where few utilities are promoting the sales of efficient refrigerators above the standards. The study could also include interviewing refrigerator manufacturers to investigate whether the California programs have caused them to ship more efficient units to other parts of the country. The scope of this study is described in the body of the report.

The study would provide estimates on the following variables:

- Total refrigerator sales in the service territory for the program year;
- Average efficiency (stated in terms of the estimated annual consumption from the DOE tests) of refrigerators sold in the service territory during the program year;
- Average adjusted volume of refrigerators sold in the service territory during the program year;
- Average efficiency of refrigerators sold in the comparison area during the program year; and
- Average adjusted volume of refrigerators sold in the comparison area during the program year.

The values of these variables would be used to estimate the net program impacts according to the calculations described below. To illustrate how this would be accomplished, an example is provided using the following numbers:

Number of Rebated Refrigerators (in thousands)	100
Average kWh of Rebated Unit	600
Average Standard kWh of Rebated Units	800
Average Adjusted Volume of Rebated Units	16
Total Number of Refrigerators Sold in Service Territory	180
Average kWh of Refrigerators Sold in Service Territory	650
Average Standard kWh of All Refrigerators Sold in Service Territory	775
Average Adjusted Volume of Refrigerators	15
Average kWh of Refrigerators Sold in the Comparison Area	740
Average Standard kWh of Refrigerators Sold in the Comparison Area	788
Average Adjusted Volume of Refrigerators Sold in the Comparison Area	15.5

The adjusted gross impact of the program is simply the reduction in kWh for rebated units from the standard times the number of rebated units. In the example, this is (800-600)*100 = 20,000.[2]

The program also has a beneficial effect of stimulating the sales of high-efficiency units outside of the program. The total impact of the program including this "spillover effect," before adjusting for free-ridership and naturally occurring efficiency increases above the standards, is simply the average reduction in kWh below the standard for all refrigerators sold in the service territory. For the example, this is (775-650)*180 = 22,500.

The effects of free-ridership and naturally occurring savings above the standards are estimated by using the information from the comparison area. The average reduction in consumption below the standards in the comparison area is applied to the total number of refrigerators sold in the state. This may be adjusted for differences in the average adjusted volumes and other characteristics between the areas.

In the example, the difference is (788-740) = 48. This might be rescaled proportionately by the adjusted volumes of units in California and in the comparison area, 15/15.5 = 0.97. This lowers the estimate to 46. This per unit saving is applied to the number of units sold in the service territory, i.e. 46*180 = 8,280. This is the estimate of the combined effects of program free-ridership impacts and how much consumers would have bought above the standards.

The net program impact is the adjusted gross program savings (20,000) plus "spillover" effects (2,500), minus the free-ridership impact (8,280). This is 14,220. The net-to-gross ratio is 14,220/20,000 = 0.71.

The first statewide study, described below in greater detail, would address some issues related to the estimation procedure proposed here. These include the effects of other utility programs on refrigerator efficiencies outside of California and the appropriate accounting for differences in adjusted volumes and other refrigerator characteristics. The method proposed for estimation of the net-to-gross ratios could be extended, in principle, to break down the ratio by efficiency range, e.g., 10 to 15 percent above standard, 15 to 25 percent, etc.

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[2]In practice, the adjusted gross impacts would be estimated for each rebated unit, then summed to obtain the total program savings. This could produce a slightly different estimate than that based on the average consumption due to aggregation.

Effective Useful Life

The estimate of the effective useful life of the rebated refrigerators would be based on the results of a statewide study. The study would estimate the effective useful life as defined in the protocols by examining the disposition of used refrigerators that leave service through various channels. It would estimate their ages and the percentages that are recycled for sale inside of California versus those that are scrapped or shipped out of the state. It could include an accounting of the migration of high efficiency refrigerators between service territories within California. The information would be used to estimate the effective useful life of the stock of refrigerators. This estimate may be adjusted to account for changes in the durability of new refrigerators versus the older stock. The estimate would be developed at a statewide level. If the results of the study indicated significant differences in the disposition of refrigerators across service territories, then procedures would be developed for modifying the estimates in each service area to account for these differences.

Rebound Effects

The effects of the utility programs in causing participants to purchase larger capacity refrigerators or to add extra features would be estimated in a statewide study and used to adjust the estimates of net program savings to account for rebound effects. The statewide study would survey samples of program participants and nonparticipants to estimate the increases in capacity and other features that they acquire when they buy new refrigerators. The differences in the average changes between the two samples would be attributed to rebound effects of the program. The estimates will be used to adjust the net program savings to account for the rebound effects.

Impacts of Second Refrigerator Recycling Programs

The procedures for estimating the impact parameters for high efficiency rebate programs have limited applicability to refrigerator recycling programs. Refrigerator recycling programs save energy primarily by reducing the in-service lives of older, inefficient refrigerators. This energy conservation benefit complements the environmental one of providing a safe disposal channel for harmful refrigerants and equipment components.

The primary issue in estimating the impact of refrigerator recycling programs is how much they reduce the in-service lives of the units that are scrapped. This could be estimated by calculating the ages of the units that are turned in and comparing these to the ages of units scrapped through normal disposal channels. This latter information would be collected as part of the effective useful life study.

The gross program impact would be estimated by determining the energy consumption of recycled units. This could be estimated based on spot metering of a sample of units that are turned in. The recycling contractors for the PG&E program that is being planned and the SCE program that is under way could conduct this spot metering as part of their program administration. The spot metering tests the electricity consumption of a sample of units using the DOE test procedures. The results of these tests would be used to estimate the gross savings due to removing the units from service.

The gross load impacts would be estimated using refrigerator load curves from PG&E's and SCE's end-use load metering studies. The load curves for a subsample that is representative of the characteristics of recycled refrigerators would be calculated from the studies. These load curves would be used to estimate the percentage of annual savings that are realized during each costing period and coincident with the system peaks.

The first-year net program impacts of the program would be estimated by surveying the program participants to determine whether the program had caused the early removal of their refrigerators and how they would have disposed of the units in the absence of the program. The information from this survey would be used in conjunction with the results of the study on effective useful lives of refrigerators to estimate the percent of the refrigerators that would have been removed from service in the absence of the program. The survey could also be used to investigate other issues surrounding the program. These include confirmation that the disposed refrigerators were actually in service prior to turn-in and whether another unit replaced the old refrigerator.

The effective useful life of the program "measure" would be defined as the net reduction in refrigerator life caused by the program. This would be estimated by comparing the age distribution of refrigerators scrapped under the program to that of refrigerators disposed of through normal channels.

RECOMMENDATIONS FOR STATEWIDE STUDIES

HBRS recommends that CADMAC commission several statewide studies to implement the proposed methods. These are presented in the recommended order of priority from most important to least important.

Statewide Study of Net-to-Gross

This study would estimate the net-to-gross impacts of the efficient refrigerator programs in California using a combination of aggregate shipments data from AHAM, sales data from a sample of retailers, and survey data from a random sample of customers. The sales weighted average efficiency of refrigerators sold in California based on the sales data would be compared with the average efficiency of units sold at the national level based on the AHAM data. The differences would be attributed to the net impact of the efficient refrigerator programs. The random customer survey would confirm whether the sales data are representative and would allow allocation of program impacts by utility service area.

This study is important because the issues of net-to-gross are significant ones in the refrigerator program. They are likely to become even more important if the California utilities move toward manufacturer rebates for high-efficiency refrigerators. The study would also serve to demonstrate the effectiveness of this approach for other technologies, such as compact fluorescent bulbs.

Effective Useful Life Study

The second study would estimate the effective useful life of refrigerators as defined in the California Collaborative. The study would track the disposition of old refrigerators by surveying households, refrigerator dealers, recycling contractors, disposal centers, and other entities that process used refrigerators. The surveys would record the ages of replaced refrigerators and the percentage of them that were re-used versus those that were scrapped. This information would be used to estimate the disposition pattern for old refrigerators and the median age of the ones that are scrapped.

Study of Refrigerator Turn-In Programs

This study would estimate the effect of turn-in programs on accelerating the scrappage rates of second refrigerators. The study would track the ages of turned in refrigerators to estimate their mean age. This estimate would be compared with that from the previous study to determine the impact of the program in reducing the effective useful life of refrigerators.

Study of Rebound Effects of Refrigerator Programs

This study would determine if there are any significant rebound effects due to efficient refrigerator programs. The study would survey program participants and nonparticipants about the sizes and features of new and replaced refrigerators. This information would be used to estimate whether there are any significant differences between participants and nonparticipants in the changes in capacity and features from old to new units.

ORGANIZATION OF THE REPORT

The remainder of this report is organized into six sections. Section 1 presents information on the activities of California utilities surrounding their promotion of high-efficiency refrigerators. Section 2 presents the results from reviewing the transferability of data across utilities. The review focuses on the estimates of gross program energy savings (kWh) and critical peak load (kW) impacts. Section 3 presents an assessment of the usefulness of refrigerator sales or wholesale shipment data as a possible basis for estimating key parameters associated with energy impacts. Section 4 presents a discussion of the existing assumptions used to estimate useful life and the data and methods used to support these assumptions. Section 5 presents a discussion of assumptions about possible rebound effects. The last section (Section 6) describes plans for studies that the California utilities will undertake to examine various issues surrounding the estimates of the impacts of their refrigerator programs.

SECTION 1: REVIEW OF EXISTING METHODS AND DATA SOURCES

This section summarizes the activities of the California electric utilities surrounding their promotions of high-efficiency refrigerators. The report describes the various programs that the utilities currently sponsor and plan to institute in the future, as well as the data collection and analysis efforts that they are conducting in support of these programs. The review of data collection and analysis encompasses those studies that are performed in support of program planning, performance tracking, evaluation, market and load research, and long-term forecasting. The review includes past, current, and planned activities.

PROGRAM DESCRIPTIONS

All three California investor owned utilities promote the sales of refrigerators that significantly surpass the federal appliance standards. The features of the programs that they sponsor are summarized in Table 1.1.

All three utilities currently use customer rebates as the primary means of promoting high-efficiency refrigerators. The programs have similar characteristics. During the summer months, the utilities offer customer rebates on new refrigerators that exceed the existing standards. SDG&E offers its program year-round. The rebate levels depend on the percentage level by which the refrigerators exceed the standards. For example, PG&E's 1991 program provided $50, $75, $100, $125, and $175 incentives to residential customers purchasing refrigerators that exceeded federal energy standards by 10, 15, 25, and 30 percent, respectively. SCE and PG&E offer their rebates through the dealers and pay customers based on applications with proof of purchase through the mail. SDG&E pays the rebate at the point of purchase through the participating dealers.

In addition to the customer rebates, SCE and PG&E sponsor some other programs aimed at high-efficiency refrigerators. PG&E pays an incentive to dealers and sales persons for each qualifying efficient refrigerator sold during the months when the customer rebates are not offered. PG&E also provides rebates to multi-family property owners who purchase two or more units at one time. Both PG&E and SCE have participated in the Super Efficient Refrigerator Program (SERP) that offered a prize to the manufacturer who developed and successfully commercialized a very high-efficiency model. They have both contributed toward the prize which was awarded to Whirlpool Corporation. PG&E and SCE also provide high-efficiency refrigerators to qualifying low-income customers under their Customer Assistance Programs.

In the future, the three utilities plan some changes to their programs. PG&E is planning to offer rebates in 1994, but will modify the eligibility requirements. SDG&E is currently reviewing bids by independent contractors to manage the residential programs. If it receives no acceptable bids or determines that SDG&E can deliver the program more cost effectively than the contractors, it may continue its program. SCE will continue to operate a high-efficiency refrigerator customer rebate program in 1994.

As part of the Western Utilities Consortium, the California utilities are discussing the possibility of offering rebates to manufacturers. They must still determine some method for determining the levels of sales in each utility service territory since manufacturers only track shipments down to the wholesale distribution point.

SCE has recently instituted a second refrigerator recycling program, and PG&E is in the advance planning stage of developing one. SCE's program began in late 1993. Its program offers to pick-up second refrigerators that are operating and will dispose of them in an environmentally safe manner. PG&E intends to offer a system-wide Refrigerator Turn-In Program in mid 1994.

Table 1.1: Summary of Program Descriptions

Type of Program	PG&E	SCE	SDG&E
Rebate	**1992 and 1993 Efficient Refrigerator Rebate Programs.** Rebates are provided to customers that purchase units that exceed Federal efficiency standards. Program conducted during June through September. **1994 Program.** PG&E is offering the following customer incentives for refrigerators that exceed the 1993 standards : - $25 - 20%+ - $50 - 25%+ and CFC free - $75 PG&E also is offering instant cash off coupons to all California Comfort Program participants (residential new construction) with the same incentive levels as the retail rebate program.	**1993 Refrigerator Rebate Program.** Customers receive rebates for purchasing refrigerators that exceed standards by at least 10 percent. Eligible models and rebate levels are listed in the program brochure. The program will process applications for all new refrigerators purchased during May through September. **1994 Program.** SCE will offer cash rebates of $30 to $100 for high efficiency refrigerators based on the efficiency of the model purchased.	**1992 and 1993 Refrigerator Component of the Appliance Efficiency Incentive Program.** Provide customers with rebates at point-of-purchase for refrigerators with efficiency ratings above the Federal standards. The participating appliance dealer discounts the purchase price and is reimbursed by the utility. **1994 Program.** Program will either be awarded to an ESCO under SDG&E's DSM bidding program, or if no ESCO bids to run a dealer program, SDG&E may continue its own program.
Super Efficient Refrigerator Program (SERP)	**1993 SERP**. A manufacturer subsidy to develop and sell super efficient refrigerators (exceeding the standard by 30%). Whirlpool was selected by committee for SERP.	**1993 SERP.** In collaboration with PG&E.	Super efficient refrigerators are a component of SDG&E's overall program.
Turn-in	PG&E is currently considering a turn-in program for old refrigerators. It has no definite plans for implementation at this time.	**Late 1993.** The program will provide incentives for the removal of operating second refrigerators.	None available. Potential for ESCO to implement a turn-in program if one submits a winning bid under SDG&E's replacement bid.

Type of Program	PG&E	SCE	SDG&E
Low-Income	As part of the **TCAP program**. Low-income customers are given new energy efficient refrigerators to replace inefficient ones.	**1993 Program.** As part of CAP, SCE provides up to $300 with a copayment of $175 for each refrigerator purchased by property managers/owners of subsidized housing. The number of refrigerators are limited to approximately 2,000 units annually. In the following year, the incentive will include an additional amount for also participating in the recycling program.	None.
Other	**PG&E** **1992 and 1993 Refrigerator Sales Person/Dealer Incentive Program.** Provides an incentive to the salesperson and the dealer for each high-efficiency unit sold. Operated during the year, except when the customer rebates are offered. **1992, 1993, and 1994 Contract Refrigerator Program.** This program is offered yearly. It is designed to meet the needs of new construction and multi-family market segments. Builders and property managers receive rebates when 2 or more refrigerators are purchased.	**SCE** **1995 Manufactures Cost Credit.** Studying a manufacturers cost credit in collaboration with the subcommittee of the Western Utility Consortium (WUC).	**SDG&E** **1995 Manufactures Cost Credit.** Studying a manufacturers cost credit in collaboration with the subcommittee of the Western Utility Consortium (WUC).

PROGRAM PLANNING METHODS AND ASSUMPTIONS

All three utilities have projected the impacts of their existing high-efficiency refrigerator programs as part of the planning process. Each of them uses the same basic approach for estimating the energy and peak demand savings of these programs. This approach is a relatively straightforward application of engineering methods based on inputs drawn from various sources.

The gross energy savings per high-efficiency refrigerator are estimated based on results of tests that manufacturers are required to perform by the Department of Energy for all refrigerators and a comparison with the minimum efficiencies mandated by the standards given assumptions about the average sizes and configurations of the rebated units (see Tables 1.2 and 1.3). For example, PG&E uses information from its 1990 and 1991 programs to estimate the volume of rebated units and the average percentage increase in efficiency associated the rebates. The estimated savings per unit are calculated from the test based estimates of electricity uses of models of this size and efficiency differential. A metering study has been completed recently to confirm the accuracy of estimates based on the DOE test procedures.

The gross peak demand impact is estimated by applying an inverse load factor to the estimate of annual electricity savings. This is simply the ratio of the peak load to the average load. This factor is drawn from past load research studies.

The net-to-gross ratio is drawn from different sources depending on the utility. SDG&E cites a 1992 CPUC decision as the basis for its estimate. PG&E bases its estimate on past experience with changes in efficiency standards and their impacts on product availability and demand.

Estimates of the effective useful life of efficient refrigerators used in program plans for past years have been based on a variety of "expert judgements" negotiated as part of different regulatory and collaborative processes. Currently, all of the utilities are using values from the DSM Measure Life Project for their DSM program planning.

The 1993 program plans make no explicit assumptions about any rebound or spillover effects from the programs. They take no credit or penalty for the effects of the program on changing the efficiency choices of nonparticipants nor influencing the features or usage of participants beyond the operating efficiency. To date, sales information does not indicate program influence on product features or type other than efficiency level.

The plans currently assume that the program effects will persist throughout the effective useful life of the unit. There will not be any degradation in the efficiency of the rebated refrigerators relative to the standard units they displaced.

The methods and assumptions used in the program planning are summarized in Tables 1.2 and 1.3.

Table 1.2: Summary of Impact Method

By Utility Requirement	PG&E	SCE	SDG&E
Program planning	1993 - Engineering estimates of energy savings based on the average unit size found in the 1991 program calculated using the 1993 Federal Refrigerator Standard for a top-mounted freezer refrigerator. The gross savings are adjusted for free-ridership. No adjustments are made for rebound and spillover effects.	1993 - Engineering estimates of energy savings are based on UECs developed from the standard DOE formula. One input to the savings calculation includes projected units by category (based on pervious year). Peak savings are based on the load shapes from the 1990 RAEUS. The gross savings are adjusted for free-ridership. No adjustments are made for rebound and spillover effects.	1993 - Engineering estimates of energy savings based on DOE/CEC UEC for an 18 cubic foot average base refrigerator, and 10% more efficient unit, and projected number of units (based on estimated market potential, given constraints on availability). The gross savings are adjusted for free-ridership (in accordance with CPUC Decision 92-09-080). No adjustments are made for rebound or spillover effects. Peak savings are based on load shapes from RELOAD that are adjusted for UEC.
DSM forecasting	The same as described above.	The DSM forecast uses the potential and measure life data from the Xenergy study, internal UEC values, and unit distributions from the program tracking system. UECs and number of participants are modified slightly for the forecast.	The same as described above, but projected market penetration is modeled without supply constraints and as a function of customer economic decision criteria.
Program tracking	Impacts based on efficiency of units sold.	Impacts based on model type of units sold.	Impacts based on efficiency of units sold.

By Utility Requirement	PG&E	SCE	SDG&E
Evaluation	UECs, energy impacts, and net-to-gross issues were examined through surveys and metering.	UECs and energy impacts were and are examined through conditional demand analysis.	Market transformation was and is examined bi-annual through inventories of floor stocks and customer surveys. Impact analysis is based on sales data.
Long-term forecast	The long term forecast is based upon an assessment of market potential, examination of program benefits and costs, and careful examination of market ability to absorb new/advanced technologies through time.	The system forecast is based on an end-use analysis that accounts for DSM. The inputs to the forecasting model include average and marginal UECs, stock, and degradation rates (based on average life, the customer forecast, and new units). The refrigeration mix is based on SCE Energy Efficiency Potential Study: Results and Methods (October 1992) and Residential Appliance Incentives: A Conditional Demand Study of End-Use kWh and Savings Estimates (June 1993).	The DSM penetration model (1) assesses the overall technical potential for the high efficiency refrigerators, (2) develops estimates of market penetration under alternative assumptions with respect to utility incentives, and (3) takes into account both economic and non-economic factors affecting penetration. The penetration model is based on an economic logistic function, utilizing customer awareness factors, attractiveness measures (including return-on-investment (ROI) estimates), and interactive competitive effects between technologies competing for market share. Saturation and penetration estimates to calibrate the model are derived from SDG&E's refrigerator rebate program database plus the most recent residential appliance saturation survey (MIRACLE).

Table 1.3: 1993 Planning Input Values

Parameter	1993 PG&E		1993 SCE		1993 SDG&E	
	value	source	value	source	value	source
Gross Energy per unit (engineering estimate)	86 kWh @10% 112 kWh @15% 146 kWh @20% 182 kWh @25% 218 kWh @30%	**Rebate Program.** Based on UEC of a typical 19.21 cu. ft. refrigerator (calculated using the 1993 Federal Refrigerator Standard for a top mounted freezer refrigerator) and the average efficiency over the standard of 11.9%, 15.5%, and 20.25% based on 1990 program results. Shown in 1993 GRC workpapers.	160 kWh	**Rebate Program.** Based on UECs calculated from DOE formulas. Documented in Demand-Side Management Unit Energy Savings (October 1, 1992). The estimate was aggregated from UECs based on actual participating refrigerators.	68 kWh @10% 117 kWh @15% 166 kWh @20%	Based on UECs from the 1990 Appliance Efficiency Regulations (CEC P400-91-029) that are adjusted for the 1993 projected distribution of 18 ft. refrigerator models. Shown in the Advice Letter 860-E, January 1993.
Gross Peak per unit (engineering estimate)	.047 kW @10% .061 kW @15% .080 kW @20% .100 kW @25% .120 kW @30%	Based on multiplying the annual energy savings by H-factors. These are derived from the Appliance Metering Project (AMP), which meters residential end-uses.	.024 kW	Based on 1990 RAEUS (metering study)	.030 kW @10% .059 kW @15% .083 kW @20%	Same as above except in terms of demand reduction.
Net-to-gross	0.8 @10% 0.9 @15% 1.0 @>20%	Assumed based on presumption that manufacturers would barely meet 1993 standards.	1.0	Negotiated with regulators.	1.0	In accordance with CPUC Decision 92-09-080
Useful life	20 years	1990 Collaborative Agreement (An Energy Efficiency Blueprint for California)	18 years	Negotiated with regulators.	20 years	Negotiated with CEC (An Energy Efficiency Blueprint for California)
Rebound	None	None	None	None	None	None
Spillover	None	None	None	None	None	None

PROGRAM EVALUATIONS

Table 1.4 summarizes the evaluation studies of refrigerator programs that the California utilities have conducted or are planning to conduct. SDG&E has performed a series of studies that survey the floor stock of refrigerators in retail stores. The objective of these studies is to examine the effect of SDG&E's program on the efficiencies of the stock of refrigerators offered in SDG&E's service territory. Table 1.5 summarizes evaluation studies that focus on end-use metering of refrigerators. This information will be used to assess transferability of load data across utilities.

PG&E has conducted a fairly comprehensive evaluation of its 1992 program. This study included surveys of program participants and nonparticipants, interviews of retailers, collection of aggregate sales and shipments data from national retail chains and trade associations, and the metering of a sample of efficient refrigerators.

Table 1.4: Summary of Evaluation Studies

Utility	Completed	On-going	Planned
PG&E	Market Evaluation of the Refrigerator Incentives Programs report (RAE-92-B07, November 1992) assessed program effects by estimating what the efficiency and other characteristics of refrigerator purchases would have been in the absence of the program. A comparison group is included. For studies on refrigeration metering refer to the table on the next page.	For studies on refrigeration metering refer to the table on the next page.	In the future, the issue of persistence will be examined. Also, dependent on statewide measurement plan.
SCE	For studies on refrigeration metering refer to the table on the next page.	For studies on refrigeration metering refer to the table on the next page.	Dependent on statewide measurement plan.
SDG&E	Studies include inventories of floor stock to assess changes in the relative mix of high energy efficient and standard refrigerators. Most recent includes Refrigerator Floor Stock Study Update, January 1993, (MIAP-92-P07-S02-R304). Also, a process and impact study was completed for the 1991 program.	Quarterly validation surveys.	Plan to address issues of participation, net-to-gross, and rebound issues in the Residential Appliance Saturation Survey. Impact study survival analysis.

Table 1.5: Refrigerator Metering

Utility	Activity/Studies
PG&E	- **Appliance Metering Project (AMP).** Ongoing metering is performed on a sample of 200 refrigerators. End-use data is available for 1992. Model information is incomplete. PG&E is working to collect the missing information and update the sample to make it more representative by including newer units. - **Current Refrigeration Metering Activity.** One year's worth of hourly end-use and temperature data was collected on 120 efficient refrigerators (exceeding Federal standards by 30 percent) from the 1992 program. The sites are located in Fresno. Simultaneously, the same type of data collected for 120 standard refrigerators (exceeding Federal standards by 10 percent) in the East Bay. The purpose of the project is to provide information on UECs, energy savings, and peak reductions of efficient refrigerators. - **Refrigerator Rebate Evaluation: 1992 Field Metering Report, RAE-92-B06, November 1992.** The report summaries the results of metering a sample of energy efficient refrigerators. The study is based on an analysis of 15 days of data from 119 refrigerators that exceed Federal standards by 10 to 15 percent. The study also examines the accuracy of the engineering estimates. - **Short-term Refrigerator Metering: Residential Refrigerator Field Metering 1991 Cases Studies, RAE-92-A04, August 1992.** The report summarizes: the measured energy savings of 20 new high-efficiency refrigerators in Fresno, California; the investigation of a in-home metering technique; and, assessment of the design for use in a statistically valid metering project.
SCE	- **Current Residential Appliance End-Use Survey Activity**: For 1992 end-use metering, the 1991 sample was augmented with approximately 80 1991 refrigerator rebate program participants with units whose efficiencies exceed the Federal standard from 15 to 30 percent. - **Residential Appliance End-Use Survey: Collection of Residential Appliance Time-Of-Use Energy Load Profiles, 1991 Results, November 1992.** RAEUS is used to collect and analyze end-use load data from a representative sample (almost 300) of residential customers. The sample size for refrigerators includes 85 units. The report contains load profiles by season and day type and UEC's by season and by peak period for refrigerators. - **Residential Appliance End-Use Survey: Collection of Residential Appliance Time-Of-Use Energy Load Profiles, 1990 Results, October June 1990.** This report summarizes the same information described above but for only 59 refrigerators. - **Residential Appliance End-Use Survey: Collection of Residential Appliance Time-Of-Use Energy Load Profiles, 1988-1989, June 1990.** This report summarizes the same information described above.
SDG&E	- None. Use load shape estimates from SCE. SDG&E feels their customers are similar enough to those of SCE's given the proximity of the service territories.

SECTION 2: TRANSFERABILITY OF DATA

HBRS reviewed the transferability of data on refrigerator program impact parameters across utilities. The general objective of this task was to determine whether the results of studies conducted for one utility or customer subpopulation to estimate key program impact parameters can be applied to estimate the program impacts for another utility or customer group. The review focused on the estimates of gross program energy (kWh) and critical period load (kW) impacts since the other impact parameters--net-to-gross ratio, effective useful life, and rebound effects--were addressed in other tasks.

All three utilities estimate the energy and critical period load impacts of their high-efficiency refrigerator programs using similar techniques. The gross energy savings per refrigerator are estimated from the California Energy Commission's listing of Federally mandated test results. The manufacturers of all refrigerators provide estimates of annual electricity consumption based on laboratory test procedures prescribed by the Department of Energy. The utilities compare the energy use estimates for the high-efficiency units to comparably sized units that just meet the minimum federal standards. The difference in energy consumption between these units is the gross savings from the program. The planning estimates of program impacts assume an average size and configuration for the rebated units based on previous program experience. The estimates for earnings claims use the estimates from the DOE mandated laboratory tests for the units that were rebated based on information tracked in the program database.

The gross peak demand impacts are estimated by applying an inverse load factor to the annual energy savings estimate. This inverse load factor is the ratio of the average peak period load to the average annual load. For example, if the average savings per refrigerator is 10 watts or 87.6 kWh per year (10 watts per hour times 8760 hours per year) and refrigerators use 50 percent more than their average load during peak periods, then the inverse load factor is 1.5 and the peak savings are 15 watts per refrigerator. The inverse load factor is calculated from general end-use load studies that the utilities conduct on an on-going basis--PG&E's Appliance Metering Project and SCE's Residential Appliance End-Use Study. Each of these metering projects uses a stratified sample of the <u>stock</u> of refrigerators in the general residential population.

The important methodological issues surrounding this approach to estimating gross energy and peak load impacts concern the reliability of the Department of Energy test results as measures of in-field energy consumption and the validity of the load curves from general end-use metering samples to estimate peak load impacts of efficient units. These are the two issues that were addressed under this task. Specifically, the analysis attempted to answer the following two questions:

1. Can the utilities use the electricity consumption from the refrigerator test results as accurate estimates of the difference in actual electricity consumption between rebated versus standard new refrigerators, or must they conduct special metering studies of high-efficiency and standard refrigerators to estimate the difference in electricity use of the two groups?

2. Can the utilities use refrigerator load curves from general end-use metering projects to estimate the peak period load savings for the efficient units or must they perform specialized studies on new efficient and standard refrigerators in their service territories?

If the answers to these questions are that utilities can use the manufacturers' refrigerator test results and generic load curves, then the estimation of the gross energy and peak load savings from high-efficiency programs is relatively straightforward. Utilities can collect information about refrigerator use based on the test results as part of the program administration and use this to estimate the annual gross energy impacts from the rebated refrigerators. The annual savings can be allocated to critical load periods by using the general load curves from end-use load metering projects. The studies to verify the reliability of the refrigerator test results could be conducted at a statewide level. The utilities could use the results of their ongoing load research projects to derive the loads.

ACCURACY OF REFRIGERATOR TEST RESULTS

To investigate the first question, HBRS reviewed the studies that the California utilities have conducted to validate the accuracy of the refrigerator test results mandated by the Department of Energy. Two such studies have been conducted. The first is a load metering study by SCE. This study is still in the field, and no results are available yet. The second study was conducted for PG&E as part of its evaluation of the 1991-92 program.

The main objective of the metering component of PG&E's 1991-92 program evaluation was to determine whether the results from the DOE mandated tests could be used to reliably estimate the gross energy savings from the efficient refrigerator program. The method for accomplishing this objective was to meter two samples of new refrigerators, each with different efficiency levels. If the difference between the metered average energy consumption for the two samples were comparable to the difference in average consumption from the tests, this would confirm the reliability of the estimates based on the tests.

Under the PG&E study, two samples of refrigerators were metered. The first sample consisted of new refrigerators that exceeded the 1990 federal standards by 30 percent or more (Group E). The second group consisted of refrigerators that exceeded the standard by 10 percent to 15 percent (Group S). The samples were drawn from program participants in the East Bay Area, clustered near Hayward and Livermore, and the Central Valley, in the Fresno area. A total of 267 refrigerators were metered, with 141 units in Group S and 126 in Group E. The samples were confined to refrigerators with top-mounted freezers and automatic defrost with volumes between 17 and 21 cubic feet to minimize sources of differences in consumption other than the efficiency levels. Both samples were metered from August 1992 to August 1993.

The key results of the metering project are summarized in Table 2.1. These are taken from the draft final report for the metering project (Pacific Gas & Electric Company Refrigerator Rebate Evaluation Draft Monitoring Report, by Proctor Engineering Group, February 10, 1994). The table presents the estimates of average consumption for each sample based on the DOE mandated test results, the metered data, and a regression analysis of the metered data. The estimates from the DOE mandated tests were taken directly from the Association of Home Appliance Manufacturers Directory that compiles the reported results for all new refrigerators. The estimates from the metered data are the simple average annualized loads for the refrigerators in each sample for the period from August 1992 to August 1993. The regression based estimates were derived by regressing average daily load against daily outside temperature for each sample. These regression models were evaluated at different temperature intervals, and a weighted average of the resulting estimates was calculated based on the distribution of temperatures in PG&E's service territory during a normal weather year.

The results show that the estimates based on the DOE tests significantly overstate the absolute average refrigerator consumption in the PG&E service territory when compared to the metered average consumption and the regression-based estimates. However, the estimates of the difference in average consumption between the two samples based on the tests results are very close to the average metered consumption and the regression estimates. The test results overestimate annual consumption by 6 to 9 percent relative to the metered averages. They are 10 to 14 percent higher than the regression based estimates. All of these differences are significant from a statistical standpoint. However, the estimate of the difference in average annual consumption between the two groups based on the test results is virtually the same as the measured average difference from the metered data and the regression-based estimate. None of the estimates are significantly different. Based on this finding, we conclude that the available evidence on the accuracy of the test results supports the finding that they provide reliable estimates of the differences in annual electricity consumption for refrigerators of different efficiencies.[3] Additional evidence on this issue will become available once SCE's metering study of 1991 energy efficient refrigerators is completed.

Table 2.1: Refrigerator Annual Consumption Estimates (kWh per year)[1]

	Standard Efficiency (Group S)	High Efficiency (Group E)	Difference
Average DOE Test Based Estimate	876	695	181
Metered Average Consumption[2]	826 (16.2)[3]	637 (12.7)	190 (20.6)
Regression Model Based Estimates[4]	796 (4.8)	611 (5.1)	185 (7.0)

1 Source: Table 2 of Pacific Gas & Electric Company Refrigerator Rebate Evaluation, Draft Monitoring Report, by Gautam Dutt and John Proctor, Proctor Engineering Group, February 10, 1994.

2 Metered average consumption is the simple annualized average consumption for all days in sample.

3 Standard errors of means in parentheses.

4 Regression based estimates reflect normal annual temperature conditions.

ACCURACY OF GENERAL REFRIGERATOR LOAD CURVES

To investigate the second question, HBRS compared the refrigerator load curves from the PG&E efficient refrigerator metering project with those from the general end-use metering projects conducted by PG&E and SCE. The hourly refrigerator load data from each of these studies were used to compute load curves for four day types--summer weekday, summer weekend, winter weekday, and winter weekend. The load curves were converted to percentages of average annual load to facilitate comparisons. For example, if a refrigerator's average load was 100 watts (or 876 kilowatt-hours per year) and its average load for summer weekday afternoons between 2 p.m. and 3 p.m. was 130 watts,

[3]The conclusion of the draft final report on the PG&E efficient refrigerator metering project is slightly different from this finding. It recommends that PG&E "utilize a small discount factor (10%)" in estimating the gross program savings. This recommendation is based on certain differences in the parameter estimates of auxiliary regressions between the two samples and a separate engineering analysis of the effects of differences in dwelling occupancy and use of anti-sweat switches between the two samples.

then its load in percentage terms would be 1.3. This normalization by annual load eliminates differences between the samples that arise purely due differences in refrigerator sizes or other factors that would affect loads proportionately throughout the year. The standard errors of the estimates of average normalized load by hour were computed and used to determine if any differences between the samples are significant or could be attributed purely to sampling variances.

The three refrigerator end-use load metering studies whose load curves were compared are PG&E's 1992 Efficient Refrigerator metering sample, PG&E's Appliance Metering Project (AMP), and SCE's Residential Appliance End-Use Survey (RAEUS). PG&E's efficient refrigerator sample consisted of new, high-efficiency refrigerators purchased in 1991 and 1992. The size and characteristics of this sample are described above.

The second refrigerator load metering study is PG&E's Appliance Metering Project. AMP collects load data on an on-going basis from a stratified random sample of refrigerators in residential dwellings, along with other end-uses. PG&E provided hourly load data from AMP for 1992. A total of 198 refrigerators were metered in 1992.

SCE's Residential Appliance End-Use Survey collects 5-minute load data for frost-free and manual defrost refrigerators from a representative sample of residential customers. The total number of refrigerators metered in the sample is 85. The refrigerator sample is stratified to contain high- and low-usage residential customers in all four SCE planning areas. SCE provided hourly load data from RAEUS for 1992.

Calculations

HBRS calculated the average normalized hourly load curves for four day types from each sample. The normalized hourly load for each hour is defined as the load in that hour divided by the average load for the entire year. An example is provided above.

These ratios were then averaged for each of the 24 hours for four day types: summer weekday, summer weekend, winter weekday, and winter weekend[4]. The associated standard errors for these hourly means were also computed.

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[4]Summer is defined as June through September and winter is defined as November through February.

The standard errors were computed to capture the fact that each observation of hourly electricity consumption is highly correlated with other observations of hourly consumption for the same refrigerator (i.e., the errors are serially correlated). Accounting for this correlation results in standard errors that are larger than if independence is assumed.

Comparisons

Figures 2.1 through 2.4 present the average normalized loads for the four day types in each sample. Tables 2.2 through 2.5 present these averages along with their standard errors. In comparing the load curves from the different samples, it is important to understand the implications of the load curve normalizations on their relative magnitudes. The overall average hourly loads in the AMP and RAEUS samples are considerably higher than those in the PG&E efficient refrigerator sample. The average loads for the AMP and RAEUS samples are 167 and 165 watts, respectively (or 1,463 and 1,445 kWh per year), whereas the average for the efficient refrigerator sample is 84 watts (or 736 kWh per year). This is reasonable since the PG&E efficient refrigerator sample consists of only new units that exceed the 1990 standard, while the other samples are representative of the older stock of refrigerators.

Once the normalizations are made however, the loads of efficient refrigerators appear higher than those of the other samples during certain time periods. This is because the loads each hour are stated as a percentage of the average for the entire year. For example, the average normalized load from 3 to 4 p.m. on summer weekdays is 1.31 for the efficient sample and 1.21 for the other samples. This means that the efficient refrigerators use, on average, 110 watts during this hour (84 watts times 1.31), and the AMP and RAEUS refrigerators use around 200 watts (167 watts times 1.21) during the same hour.

The reason that the load curves are normalized is to eliminate the effect of factors that would influence loads proportionately throughout the year. For example, outside temperature clearly affects refrigerator loads. If the milder climate in Southern California relative to Northern California tends to increase loads proportionately during all seasons however, the relative load curves from SCE could be used in PG&E's service territory to allocate annual energy savings to critical loads periods.

Any differences between the relative load curves are due to effects that influence the loads in one sample during certain times of the year disproportionately more than they do in the other samples. For example, if the climate differences between Northern and Southern California affect refrigerator loads more during the winter than the summer, then this would show up in differences in the relative loads.

Tables 2.6 through 2.17 present the pairwise comparisons of the hourly loads from each sample by day type and the standard errors of the estimates of differences. The tables also indicate whether the differences are significant at the 95 percent confidence level. The comparisons show that the relative loads from the PG&E Efficient Refrigerator sample during the summer months (both weekend and weekdays) are consistently higher than those in each of the other samples. During summer weekday afternoons, for example, the PG&E efficient refrigerator (relative) loads range from 13 percent to 24 percent greater than the PG&E AMP (relative) loads (Table 2.14). The efficient refrigerator loads are also consistently higher than those for the RAEUS sample during the summer, although not by as great a margin. During the winter months, the loads from all three samples are fairly similar. As indicated in Tables 2.10 through 2.13, the differences between means in the SCE RAEUS sample and in the PG&E AMP sample are, with some exceptions, not statistically significant.

IMPLICATIONS FOR PEAK LOAD SAVINGS

The comparisons of the average hourly loads from PG&E's efficient refrigerator sample with those from PG&E's Appliance Metering Project and SCE's Residential Appliance End-Use Study indicate that new refrigerators exceeding the 1990 standards use a higher percentage of their annual consumption during summer peak load periods. A separate analysis (not presented in this report) of the differences of loads between the two subsamples of 10 to 15 percent above standard refrigerators with those more than 30 percent above standard found no statistically significant differences in the hourly loads between the two.

The findings from these comparisons indicate that the California utilities underestimate the summer load savings from their efficient refrigerator programs when they use the data from their general end-use load studies. Since new refrigerators exceeding the 1990 standards use a higher proportion of their annual loads during the summer critical periods, more of the savings that the programs produce by moving buyers to higher efficiency units will be realized during those times.

For example, suppose that the adjusted gross annual savings for a high efficiency refrigerator were estimated to be 100 kWh per year. This estimate would typically be based on the estimate of the annual energy consumption from the rebated refrigerator derived using the Department of Energy test procedures, subtracted from the maximum allowable consumption for a new refrigerator with the same volume and features allowed by the standards. The general load study might suggest that, say, 10% of annual consumption is used during the summer peak period. Applying this percentage to the annual savings estimate would imply that 10 kWh is saved during the sumer peak. However, the load data from new refrigerators, both those that qualify for the rebate and those that just meet the standard, indicates that these units use, say, 15% during the summer peak. This percentage implies that the program saves 15 kWh during the summer peak by moving customers from the standard new refrigerator to the high efficiency unit. This latter estimate is more accurate since it is based on load data from new refrigerators.

Given the fact that the PG&E efficient refrigerator sample was confined to refrigerators with top-mounted freezers in limited geographical areas of the service territory, it may be advisable to corroborate this finding through further data collection and analysis. The results should be compared with those from SCE's sample of new refrigerators, once data from that metering effort becomes available. Further analysis might include comparing the load curves from the various samples for the same chronological period, performing regressions of loads against ambient temperature, and examining extreme temperature days.

Figure 2.1: Comparison of Normalized Refrigerator Loads--Summer Weekdays

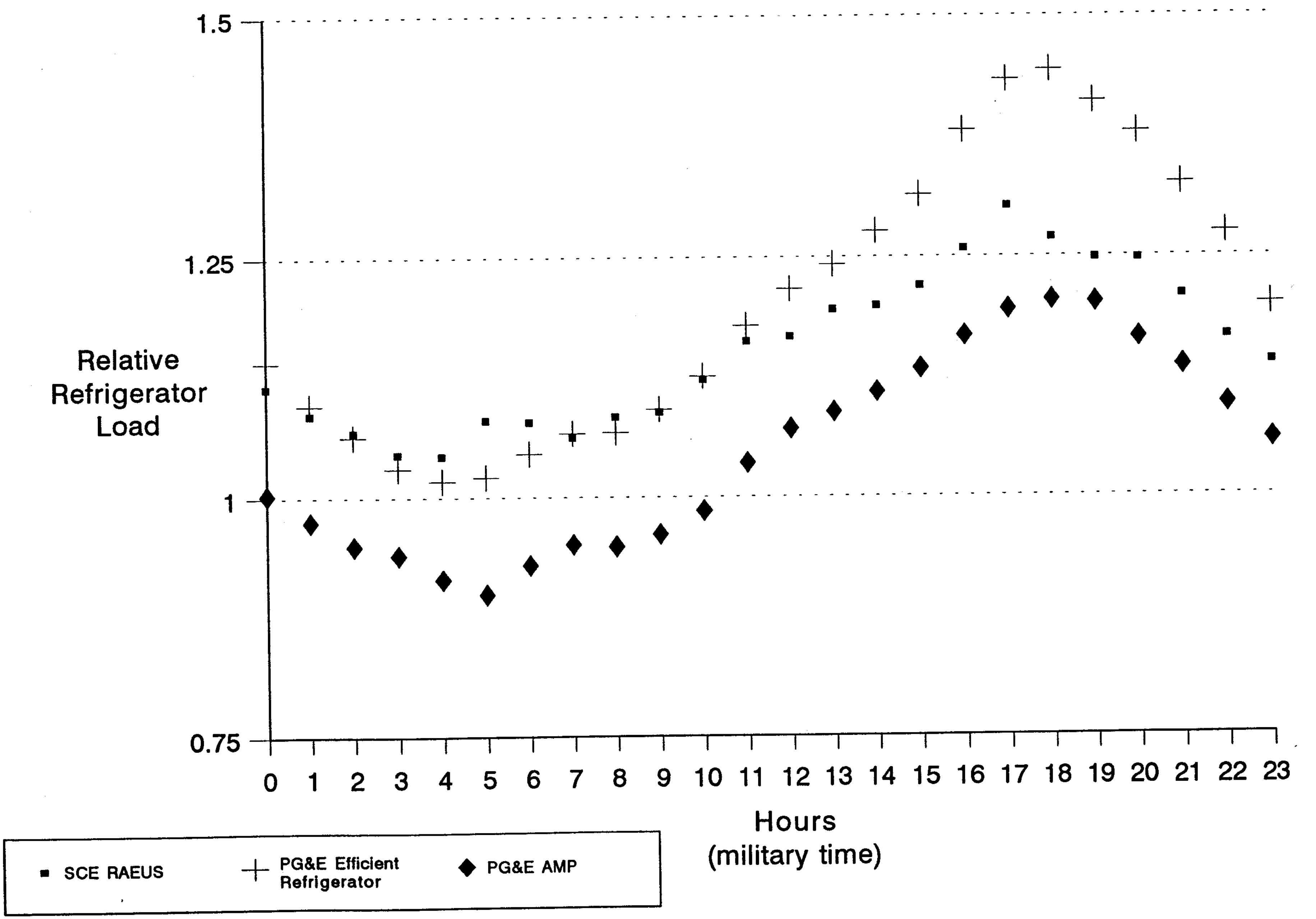

Figure 2.2: Comparison of Normalized Refrigerator Loads--Summer Weekends

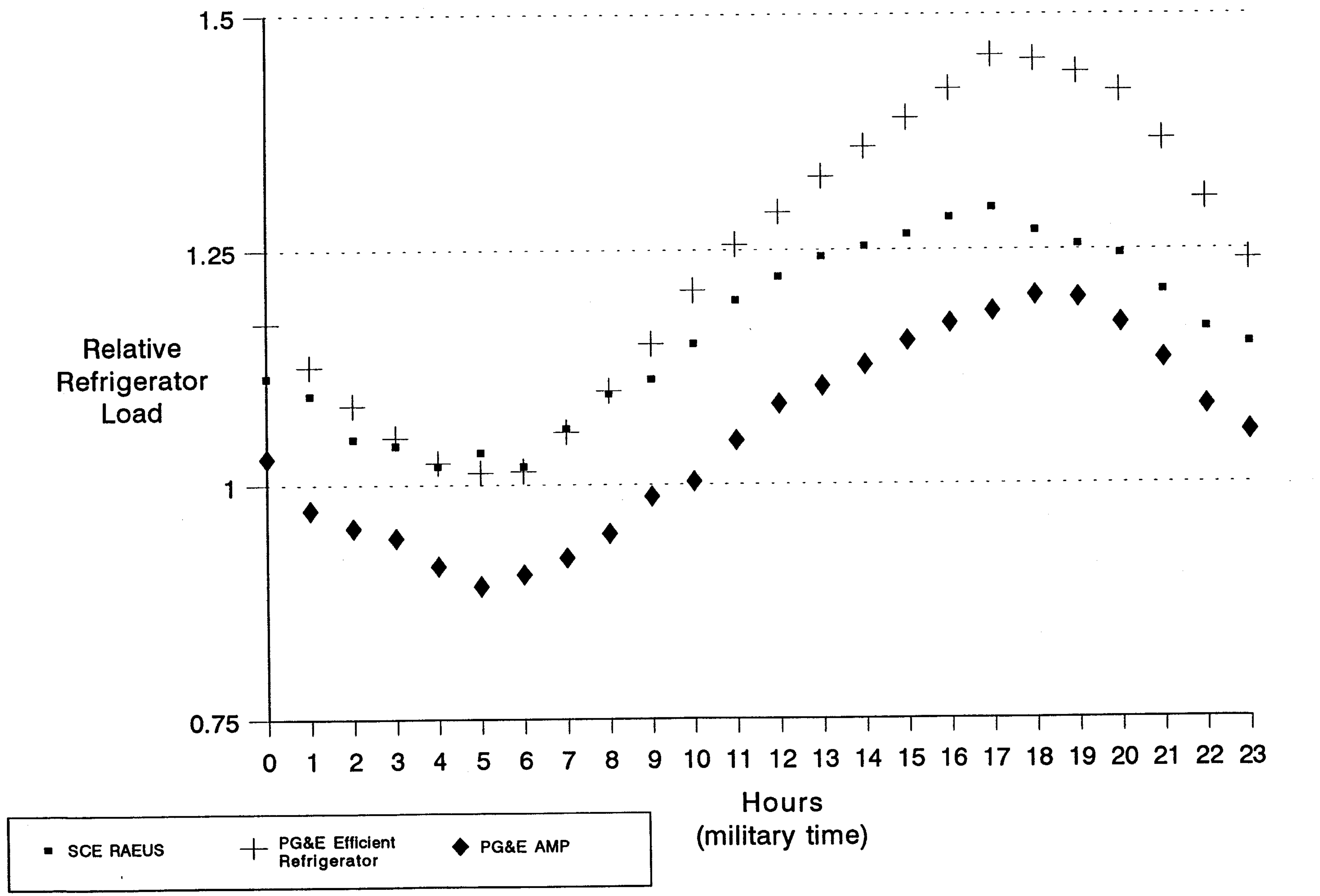

Figure 2.3: Comparison of Normalized Refrigerator Loads--Winter Weekdays

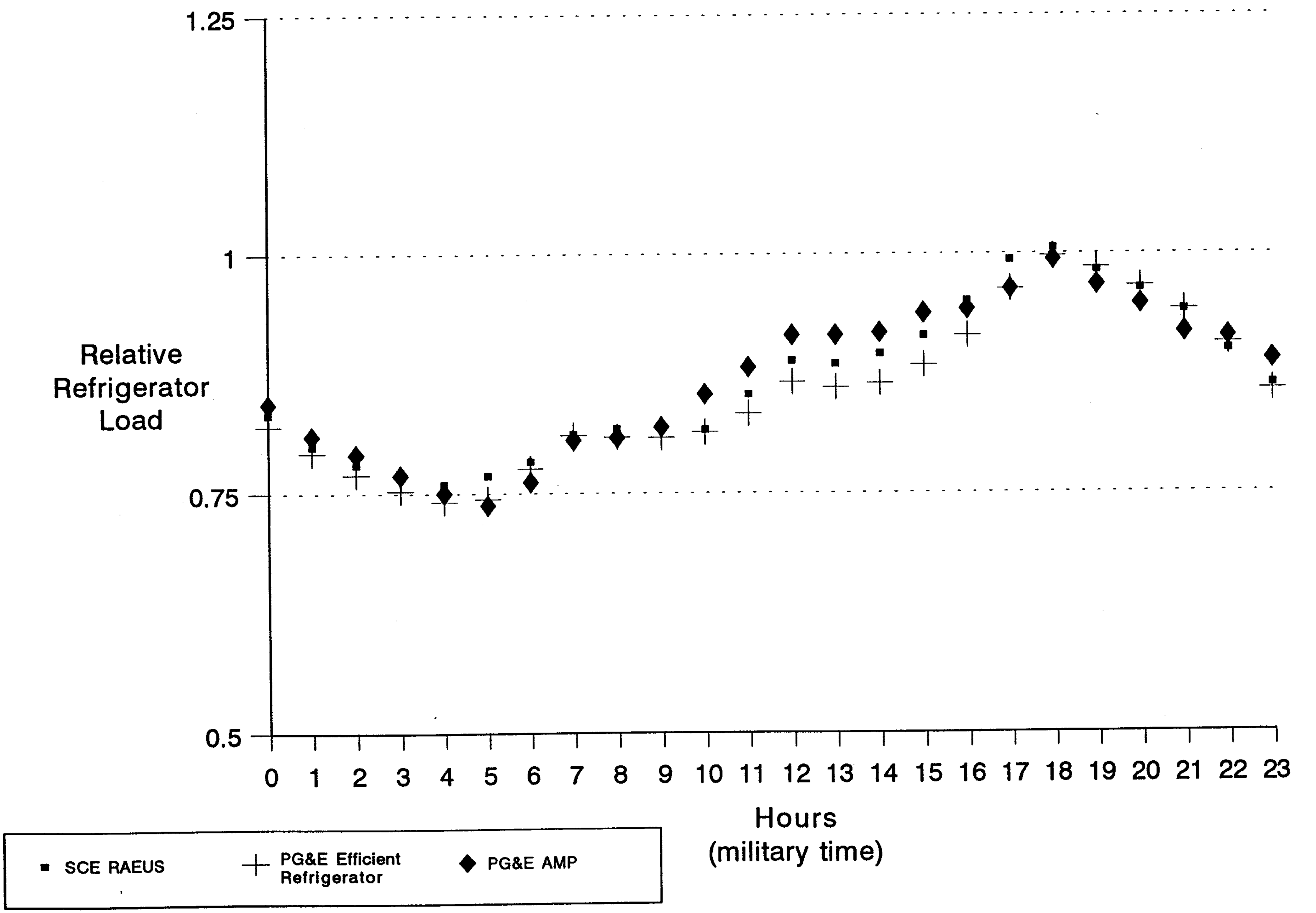

Figure 2.4: Comparison of Normalized Refrigerator Loads--Winter Weekends

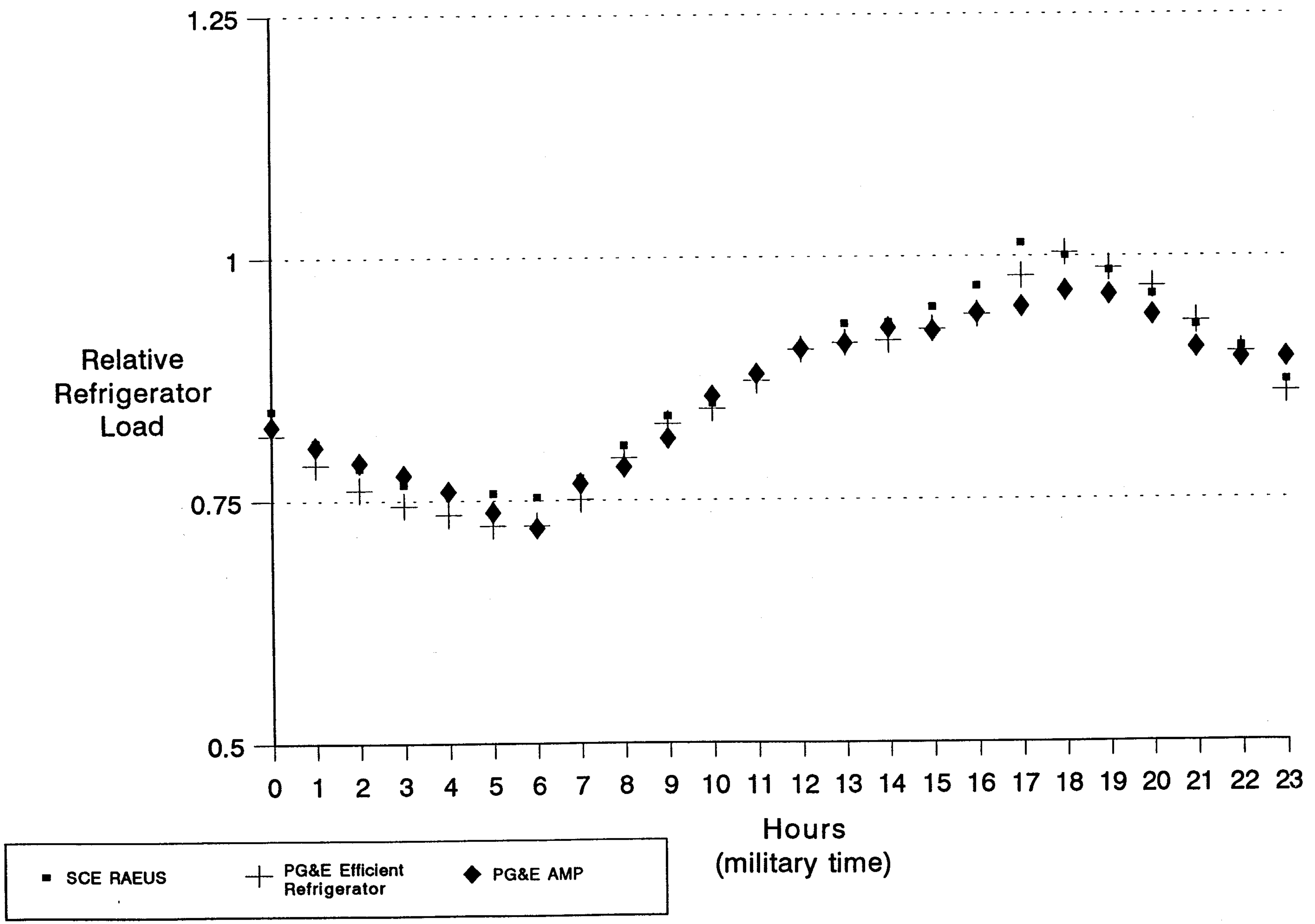

Table 2-2
Comparison of Normalized Refrigerator Loads
All Studies
Summer Weekdays

Hour	SCE RAEUS		PG&E Eff. Ref.		PG&E AMP	
	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
12 Midnight- 1 AM	1.1148	0.02400	1.1412	0.00783	1.0024	0.04473
1 AM - 2 AM	1.0858	0.02522	1.0962	0.00762	0.9741	0.04328
2 AM - 3 AM	1.0677	0.02604	1.0631	0.00755	0.9486	0.04311
3 AM - 4 AM	1.0448	0.02625	1.0299	0.00730	0.9390	0.04277
4 AM - 5 AM	1.0428	0.02527	1.0171	0.00787	0.9137	0.04145
5 AM - 6 AM	1.0799	0.02637	1.0210	0.00783	0.8980	0.04016
6 AM - 7 AM	1.0782	0.01894	1.0452	0.00829	0.9286	0.04288
7 AM - 8 AM	1.0617	0.01652	1.0665	0.00769	0.9500	0.04292
8 AM - 9 AM	1.0834	0.02074	1.0674	0.00680	0.9478	0.04262
9 AM - 10 AM	1.0885	0.01951	1.0914	0.00776	0.9605	0.04469
10 AM - 11 AM	1.1224	0.01853	1.1259	0.00882	0.9851	0.04593
11 AM - 12 Noon	1.1621	0.01973	1.1785	0.00969	1.0346	0.05019
12 Noon - 1 PM	1.1671	0.02026	1.2167	0.01031	1.0702	0.05123
1 PM - 2 PM	1.1945	0.02134	1.2421	0.00977	1.0878	0.05304
2 PM - 3 PM	1.1984	0.02151	1.2767	0.01038	1.1085	0.05542
3 PM - 4PM	1.2192	0.02095	1.3146	0.01109	1.1330	0.05640
4 PM - 5 PM	1.2578	0.02114	1.3810	0.01198	1.1673	0.05802
5 PM - 6 PM	1.3023	0.02599	1.4331	0.01120	1.1945	0.05833
6 PM - 7 PM	1.2696	0.02647	1.4434	0.01068	1.2041	0.05733
7 PM - 8 PM	1.2480	0.02444	1.4108	0.01066	1.2016	0.05574
8 PM - 9 PM	1.2471	0.02349	1.3790	0.01026	1.1649	0.05332
9 PM - 10 PM	1.2086	0.02295	1.3264	0.00976	1.1352	0.05089
10 PM - 11 PM	1.1659	0.02074	1.2748	0.00985	1.0953	0.04880
11 PM - 12 Midnight	1.1390	0.01676	1.1998	0.00896	1.0577	0.04742

Table 2-3
Comparison of Normalized Refrigerator Loads
All Studies
Summer Weekends

Hour	SCE RAEUS		PG&E Eff. Ref.		PG&E AMP	
	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
12 Midnight- 1 AM	1.1139	0.02575	1.1721	0.00917	1.0277	0.04578
1 AM - 2 AM	1.0952	0.02740	1.1260	0.00871	0.9726	0.04331
2 AM - 3 AM	1.0483	0.02764	1.0844	0.00850	0.9533	0.04346
3 AM - 4 AM	1.0415	0.02811	1.0503	0.00824	0.9428	0.04292
4 AM - 5 AM	1.0196	0.02576	1.0234	0.00857	0.9126	0.04146
5 AM - 6 AM	1.0341	0.02589	1.0128	0.00824	0.8912	0.04007
6 AM - 7 AM	1.0191	0.01862	1.0143	0.00780	0.9036	0.04110
7 AM - 8 AM	1.0593	0.02026	1.0557	0.00831	0.9213	0.04187
8 AM - 9 AM	1.0963	0.02128	1.0998	0.00825	0.9469	0.04339
9 AM - 10 AM	1.1121	0.02000	1.1501	0.00959	0.9867	0.04660
10 AM - 11 AM	1.1502	0.01854	1.2067	0.01014	1.0026	0.04629
11 AM - 12 Noon	1.1961	0.02079	1.2560	0.01089	1.0462	0.04979
12 Noon - 1 PM	1.2210	0.02223	1.2910	0.01079	1.0851	0.05139
1 PM - 2 PM	1.2425	0.02013	1.3288	0.01190	1.1041	0.05445
2 PM - 3 PM	1.2538	0.02011	1.3603	0.01135	1.1271	0.05600
3 PM - 4PM	1.2664	0.02093	1.3903	0.01166	1.1527	0.05682
4 PM - 5 PM	1.2848	0.02062	1.4211	0.01222	1.1716	0.05751
5 PM - 6 PM	1.2954	0.02466	1.4566	0.01216	1.1840	0.05727
6 PM - 7 PM	1.2703	0.02256	1.4522	0.01246	1.2008	0.05693
7 PM - 8 PM	1.2558	0.02285	1.4389	0.01180	1.1982	0.05519
8 PM - 9 PM	1.2454	0.02430	1.4193	0.01170	1.1714	0.05405
9 PM - 10 PM	1.2061	0.02470	1.3686	0.01129	1.1336	0.05098
10 PM - 11 PM	1.1665	0.02199	1.3059	0.01110	1.0832	0.04878
11 PM - 12 Midnight	1.1503	0.01733	1.2400	0.01064	1.0556	0.04826

Table 2-4
Comparison of Normalized Refrigerator Loads
All Studies
Winter Weekdays

Hour	SCE RAEUS		PG&E Eff. Ref.		PG&E AMP	
	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
12 Midnight- 1 AM	0.8320	0.01890	0.8200	0.00676	0.8430	0.05717
1 AM - 2 AM	0.7992	0.01911	0.7922	0.00673	0.8094	0.05473
2 AM - 3 AM	0.7796	0.02126	0.7694	0.00651	0.7903	0.05027
3 AM - 4 AM	0.7670	0.02046	0.7526	0.00681	0.7684	0.04876
4 AM - 5 AM	0.7591	0.01995	0.7412	0.00699	0.7496	0.04556
5 AM - 6 AM	0.7684	0.02146	0.7439	0.00718	0.7374	0.04421
6 AM - 7 AM	0.7824	0.01953	0.7756	0.00870	0.7612	0.04810
7 AM - 8 AM	0.8109	0.01663	0.8100	0.00862	0.8047	0.05040
8 AM - 9 AM	0.8168	0.01880	0.8081	0.00776	0.8074	0.05166
9 AM - 10 AM	0.8172	0.01760	0.8076	0.00715	0.8184	0.05431
10 AM - 11 AM	0.8158	0.01679	0.8133	0.00710	0.8528	0.05904
11 AM - 12 Noon	0.8526	0.01915	0.8326	0.00746	0.8812	0.06191
12 Noon - 1 PM	0.8880	0.01841	0.8656	0.00747	0.9145	0.06271
1 PM - 2 PM	0.8847	0.01675	0.8600	0.00689	0.9148	0.06449
2 PM - 3 PM	0.8954	0.01832	0.8646	0.00661	0.9170	0.06172
3 PM - 4PM	0.9140	0.01763	0.8834	0.00702	0.9375	0.06391
4 PM - 5 PM	0.9497	0.01826	0.9141	0.00812	0.9416	0.06591
5 PM - 6 PM	0.9931	0.02125	0.9629	0.00884	0.9627	0.06135
6 PM - 7 PM	1.0056	0.02028	0.9971	0.00950	0.9932	0.07117
7 PM - 8 PM	0.9822	0.01804	0.9854	0.00899	0.9670	0.06193
8 PM - 9 PM	0.9630	0.01817	0.9656	0.00883	0.9469	0.06548
9 PM - 10 PM	0.9402	0.01898	0.9409	0.00818	0.9174	0.06276
10 PM - 11 PM	0.8990	0.02021	0.9061	0.00776	0.9129	0.06551
11 PM - 12 Midnight	0.8627	0.01906	0.8574	0.00716	0.8889	0.06129

Table 2-5
Comparison of Normalized Refrigerator Loads
All Studies
Winter Weekends

Hour	SCE RAEUS		PG&E Eff. Ref.		PG&E AMP	
	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
12 Midnight- 1 AM	0.8428	0.01837	0.8171	0.00774	0.8259	0.05818
1 AM - 2 AM	0.8095	0.02059	0.7869	0.00721	0.8050	0.05157
2 AM - 3 AM	0.7833	0.02024	0.7609	0.00711	0.7886	0.05574
3 AM - 4 AM	0.7665	0.02159	0.7444	0.00715	0.7755	0.05438
4 AM - 5 AM	0.7616	0.01985	0.7352	0.00734	0.7591	0.05105
5 AM - 6 AM	0.7570	0.02224	0.7238	0.00721	0.7375	0.04762
6 AM - 7 AM	0.7531	0.02052	0.7238	0.00794	0.7211	0.04769
7 AM - 8 AM	0.7724	0.01677	0.7508	0.00802	0.7668	0.05308
8 AM - 9 AM	0.8059	0.01805	0.7932	0.00843	0.7839	0.04624
9 AM - 10 AM	0.8362	0.01784	0.8286	0.00838	0.8130	0.05235
10 AM - 11 AM	0.8493	0.01567	0.8436	0.00793	0.8569	0.05179
11 AM - 12 Noon	0.8790	0.01820	0.8728	0.00778	0.8793	0.06110
12 Noon - 1 PM	0.9053	0.01946	0.9048	0.00863	0.9050	0.06234
1 PM - 2 PM	0.9306	0.01982	0.9115	0.00797	0.9104	0.05527
2 PM - 3 PM	0.9316	0.01980	0.9139	0.00783	0.9264	0.05782
3 PM - 4PM	0.9475	0.01719	0.9252	0.00719	0.9236	0.05670
4 PM - 5 PM	0.9690	0.01969	0.9402	0.00817	0.9409	0.06372
5 PM - 6 PM	1.0139	0.02229	0.9795	0.00916	0.9479	0.06335
6 PM - 7 PM	1.0001	0.02183	1.0034	0.01014	0.9641	0.06507
7 PM - 8 PM	0.9850	0.02099	0.9877	0.01025	0.9602	0.06944
8 PM - 9 PM	0.9604	0.02032	0.9689	0.00963	0.9393	0.06372
9 PM - 10 PM	0.9289	0.01919	0.9328	0.00905	0.9055	0.05846
10 PM - 11 PM	0.9070	0.01993	0.9013	0.00808	0.8954	0.06220
11 PM - 12 Midnight	0.8717	0.01847	0.8606	0.00767	0.8957	0.06695

Table 2-6
Comparison of Normalized Refrigerator Loads
PG&E Efficient Refrigerators and SCE RAEUS
Summer Weekends

Hour	SCE RAEUS		PG&E Eff. Ref.		T - Ratio	Difference Significant at 95% Conf. Level
	Mean	Standard Error	Mean	Standard Error		
12 Midnight- 1 AM	1.1148	0.02400	1.1412	0.00783	-1.05	NO
1 AM - 2 AM	1.0858	0.02522	1.0962	0.00762	-0.40	NO
2 AM - 3 AM	1.0677	0.02604	1.0631	0.00755	0.17	NO
3 AM - 4 AM	1.0448	0.02625	1.0299	0.00730	0.55	NO
4 AM - 5 AM	1.0428	0.02527	1.0171	0.00787	0.97	NO
5 AM - 6 AM	1.0799	0.02637	1.0210	0.00783	2.14	YES
6 AM - 7 AM	1.0782	0.01894	1.0452	0.00829	1.60	NO
7 AM - 8 AM	1.0617	0.01652	1.0665	0.00769	-0.26	NO
8 AM - 9 AM	1.0834	0.02074	1.0674	0.00680	0.73	NO
9 AM - 10 AM	1.0885	0.01951	1.0914	0.00776	-0.13	NO
10 AM - 11 AM	1.1224	0.01853	1.1259	0.00882	-0.17	NO
11 AM - 12 Noon	1.1621	0.01973	1.1785	0.00969	-0.75	NO
12 Noon - 1 PM	1.1671	0.02026	1.2167	0.01031	-2.18	YES
1 PM - 2 PM	1.1945	0.02134	1.2421	0.00977	-2.03	YES
2 PM - 3 PM	1.1984	0.02151	1.2767	0.01038	-3.28	YES
3 PM - 4PM	1.2192	0.02095	1.3146	0.01109	-4.02	YES
4 PM - 5 PM	1.2578	0.02114	1.3810	0.01198	-5.07	YES
5 PM - 6 PM	1.3023	0.02599	1.4331	0.01120	-4.62	YES
6 PM - 7 PM	1.2696	0.02647	1.4434	0.01068	-6.09	YES
7 PM - 8 PM	1.2480	0.02444	1.4108	0.01066	-6.11	YES
8 PM - 9 PM	1.2471	0.02349	1.3790	0.01026	-5.14	YES
9 PM - 10 PM	1.2086	0.02295	1.3264	0.00976	-4.72	YES
10 PM - 11 PM	1.1659	0.02074	1.2748	0.00985	-4.74	YES
11 PM - 12 Midnight	1.1390	0.01676	1.1998	0.00896	-3.20	YES

Table 2-7
Comparison of Normalized Refrigerator Loads
PG&E Efficient Refrigerators and SCE RAEUS
Summer Weekends

Hour	SCE RAEUS Mean	SCE RAEUS Standard Error	PG&E Eff. Ref. Mean	PG&E Eff. Ref. Standard Error	T - Ratio	Difference Significant at 95% Conf. Level
12 Midnight- 1 AM	1.1139	0.02575	1.1721	0.00917	-2.13	YES
1 AM - 2 AM	1.0952	0.02740	1.1260	0.00871	-1.07	NO
2 AM - 3 AM	1.0483	0.02764	1.0844	0.00850	-1.25	NO
3 AM - 4 AM	1.0415	0.02811	1.0503	0.00824	-0.30	NO
4 AM - 5 AM	1.0196	0.02576	1.0234	0.00857	-0.14	NO
5 AM - 6 AM	1.0341	0.02589	1.0128	0.00824	0.78	NO
6 AM - 7 AM	1.0191	0.01862	1.0143	0.00780	0.24	NO
7 AM - 8 AM	1.0593	0.02026	1.0557	0.00831	0.16	NO
8 AM - 9 AM	1.0963	0.02128	1.0998	0.00825	-0.15	NO
9 AM - 10 AM	1.1121	0.02000	1.1501	0.00959	-1.71	NO
10 AM - 11 AM	1.1502	0.01854	1.2067	0.01014	-2.68	YES
11 AM - 12 Noon	1.1961	0.02079	1.2560	0.01089	-2.56	YES
12 Noon - 1 PM	1.2210	0.02223	1.2910	0.01079	-2.83	YES
1 PM - 2 PM	1.2425	0.02013	1.3288	0.01190	-3.69	YES
2 PM - 3 PM	1.2538	0.02011	1.3603	0.01135	-4.61	YES
3 PM - 4PM	1.2664	0.02093	1.3903	0.01166	-5.17	YES
4 PM - 5 PM	1.2848	0.02062	1.4211	0.01222	-5.69	YES
5 PM - 6 PM	1.2954	0.02466	1.4566	0.01216	-5.86	YES
6 PM - 7 PM	1.2703	0.02256	1.4522	0.01246	-7.06	YES
7 PM - 8 PM	1.2558	0.02285	1.4389	0.01180	-7.12	YES
8 PM - 9 PM	1.2454	0.02430	1.4193	0.01170	-6.45	YES
9 PM - 10 PM	1.2061	0.02470	1.3686	0.01129	-5.98	YES
10 PM - 11 PM	1.1665	0.02199	1.3059	0.01110	-5.66	YES
11 PM - 12 Midnight	1.1503	0.01733	1.2400	0.01064	-4.41	YES

Table 2-8
Comparison of Normalized Refrigerator Loads
PG&E Efficient Refrigerators and SCE RAEUS
Winter Weekdays

Hour	SCE RAEUS		PG&E Eff. Ref.		T - Ratio	Difference Significant at 95% Conf. Level
	Mean	Standard Error	Mean	Standard Error		
12 Midnight- 1 AM	0.8320	0.01890	0.8200	0.00676	0.60	NO
1 AM - 2 AM	0.7992	0.01911	0.7922	0.00673	0.34	NO
2 AM - 3 AM	0.7796	0.02126	0.7694	0.00651	0.46	NO
3 AM - 4 AM	0.7670	0.02046	0.7526	0.00681	0.67	NO
4 AM - 5 AM	0.7591	0.01995	0.7412	0.00699	0.85	NO
5 AM - 6 AM	0.7684	0.02146	0.7439	0.00718	1.09	NO
6 AM - 7 AM	0.7824	0.01953	0.7756	0.00870	0.32	NO
7 AM - 8 AM	0.8109	0.01663	0.8100	0.00862	0.05	NO
8 AM - 9 AM	0.8168	0.01880	0.8081	0.00776	0.43	NO
9 AM - 10 AM	0.8172	0.01760	0.8076	0.00715	0.51	NO
10 AM - 11 AM	0.8158	0.01679	0.8133	0.00710	0.14	NO
11 AM - 12 Noon	0.8526	0.01915	0.8326	0.00746	0.97	NO
12 Noon - 1 PM	0.8880	0.01841	0.8656	0.00747	1.13	NO
1 PM - 2 PM	0.8847	0.01675	0.8600	0.00689	1.36	NO
2 PM - 3 PM	0.8954	0.01832	0.8646	0.00661	1.58	NO
3 PM - 4PM	0.9140	0.01763	0.8834	0.00702	1.62	NO
4 PM - 5 PM	0.9497	0.01826	0.9141	0.00812	1.78	NO
5 PM - 6 PM	0.9931	0.02125	0.9629	0.00884	1.31	NO
6 PM - 7 PM	1.0056	0.02028	0.9971	0.00950	0.38	NO
7 PM - 8 PM	0.9822	0.01804	0.9854	0.00899	-0.16	NO
8 PM - 9 PM	0.9630	0.01817	0.9656	0.00883	-0.13	NO
9 PM - 10 PM	0.9402	0.01898	0.9409	0.00818	-0.03	NO
10 PM - 11 PM	0.8990	0.02021	0.9061	0.00776	-0.32	NO
11 PM - 12 Midnight	0.8627	0.01906	0.8574	0.00716	0.26	NO

Table 2-9
Comparison of Normalized Refrigerator Loads
PG&E Efficient Refrigerators and SCE RAEUS
Winter Weekends

Hour	SCE RAEUS		PG&E Eff. Ref.		T - Ratio	Difference Significant at 95% Conf. Level
	Mean	Standard Error	Mean	Standard Error		
12 Midnight- 1 AM	0.8428	0.01837	0.8171	0.00774	1.29	NO
1 AM - 2 AM	0.8095	0.02059	0.7869	0.00721	1.03	NO
2 AM - 3 AM	0.7833	0.02024	0.7609	0.00711	1.05	NO
3 AM - 4 AM	0.7665	0.02159	0.7444	0.00715	0.97	NO
4 AM - 5 AM	0.7616	0.01985	0.7352	0.00734	1.25	NO
5 AM - 6 AM	0.7570	0.02224	0.7238	0.00721	1.42	NO
6 AM - 7 AM	0.7531	0.02052	0.7238	0.00794	1.33	NO
7 AM - 8 AM	0.7724	0.01677	0.7508	0.00802	1.16	NO
8 AM - 9 AM	0.8059	0.01805	0.7932	0.00843	0.64	NO
9 AM - 10 AM	0.8362	0.01784	0.8286	0.00838	0.39	NO
10 AM - 11 AM	0.8493	0.01567	0.8436	0.00793	0.32	NO
11 AM - 12 Noon	0.8790	0.01820	0.8728	0.00778	0.31	NO
12 Noon - 1 PM	0.9053	0.01946	0.9048	0.00863	0.02	NO
1 PM - 2 PM	0.9306	0.01982	0.9115	0.00797	0.89	NO
2 PM - 3 PM	0.9316	0.01980	0.9139	0.00783	0.83	NO
3 PM - 4PM	0.9475	0.01719	0.9252	0.00719	1.20	NO
4 PM - 5 PM	0.9690	0.01969	0.9402	0.00817	1.35	NO
5 PM - 6 PM	1.0139	0.02229	0.9795	0.00916	1.43	NO
6 PM - 7 PM	1.0001	0.02183	1.0034	0.01014	-0.14	NO
7 PM - 8 PM	0.9850	0.02099	0.9877	0.01025	-0.12	NO
8 PM - 9 PM	0.9604	0.02032	0.9689	0.00963	-0.38	NO
9 PM - 10 PM	0.9289	0.01919	0.9328	0.00905	-0.18	NO
10 PM - 11 PM	0.9070	0.01993	0.9013	0.00808	0.27	NO
11 PM - 12 Midnight	0.8717	0.01847	0.8606	0.00767	0.56	NO

Table 2-10
Comparison of Normalized Refrigerator Loads
PG&E AMP and SCE RAEUS
Summer Weekdays

Hour	SCE RAEUS		PG&E AMP		T - Ratio	Difference Significant at 95% Conf. Level
	Mean	Standard Error	Mean	Standard Error		
12 Midnight- 1 AM	1.1148	0.02400	1.0024	0.04473	2.21	YES
1 AM - 2 AM	1.0858	0.02522	0.9741	0.04328	2.23	YES
2 AM - 3 AM	1.0677	0.02604	0.9486	0.04311	2.36	YES
3 AM - 4 AM	1.0448	0.02625	0.9390	0.04277	2.11	YES
4 AM - 5 AM	1.0428	0.02527	0.9137	0.04145	2.66	YES
5 AM - 6 AM	1.0799	0.02637	0.8980	0.04016	3.79	YES
6 AM - 7 AM	1.0782	0.01894	0.9286	0.04288	3.19	YES
7 AM - 8 AM	1.0617	0.01652	0.9500	0.04292	2.43	YES
8 AM - 9 AM	1.0834	0.02074	0.9478	0.04262	2.86	YES
9 AM - 10 AM	1.0885	0.01951	0.9605	0.04469	2.63	YES
10 AM - 11 AM	1.1224	0.01853	0.9851	0.04593	2.77	YES
11 AM - 12 Noon	1.1621	0.01973	1.0346	0.05019	2.36	YES
12 Noon - 1 PM	1.1671	0.02026	1.0702	0.05123	1.76	NO
1 PM - 2 PM	1.1945	0.02134	1.0878	0.05304	1.87	NO
2 PM - 3 PM	1.1984	0.02151	1.1085	0.05542	1.51	NO
3 PM - 4PM	1.2192	0.02095	1.1330	0.05640	1.43	NO
4 PM - 5 PM	1.2578	0.02114	1.1673	0.05802	1.47	NO
5 PM - 6 PM	1.3023	0.02599	1.1945	0.05833	1.69	NO
6 PM - 7 PM	1.2696	0.02647	1.2041	0.05733	1.04	NO
7 PM - 8 PM	1.2480	0.02444	1.2016	0.05574	0.76	NO
8 PM - 9 PM	1.2471	0.02349	1.1649	0.05332	1.41	NO
9 PM - 10 PM	1.2086	0.02295	1.1352	0.05089	1.31	NO
10 PM - 11 PM	1.1659	0.02074	1.0953	0.04880	1.33	NO
11 PM - 12 Midnight	1.1390	0.01676	1.0577	0.04742	1.62	NO

Table 2-11
Comparison of Normalized Refrigerator Loads
PG&E AMP and SCE RAEUS
Summer Weekends

Hour	SCE RAEUS		PG&E AMP		T - Ratio	Difference Significant at 95% Conf. Level
	Mean	Standard Error	Mean	Standard Error		
12 Midnight- 1 AM	1.1139	0.02575	1.0277	0.04578	1.64	NO
1 AM - 2 AM	1.0952	0.02740	0.9726	0.04331	2.39	YES
2 AM - 3 AM	1.0483	0.02764	0.9533	0.04346	1.85	NO
3 AM - 4 AM	1.0415	0.02811	0.9428	0.04292	1.93	NO
4 AM - 5 AM	1.0196	0.02576	0.9126	0.04146	2.19	YES
5 AM - 6 AM	1.0341	0.02589	0.8912	0.04007	2.99	YES
6 AM - 7 AM	1.0191	0.01862	0.9036	0.04110	2.56	YES
7 AM - 8 AM	1.0593	0.02026	0.9213	0.04187	2.97	YES
8 AM - 9 AM	1.0963	0.02128	0.9469	0.04339	3.09	YES
9 AM - 10 AM	1.1121	0.02000	0.9867	0.04660	2.47	YES
10 AM - 11 AM	1.1502	0.01854	1.0026	0.04629	2.96	YES
11 AM - 12 Noon	1.1961	0.02079	1.0462	0.04979	2.78	YES
12 Noon - 1 PM	1.2210	0.02223	1.0851	0.05139	2.43	YES
1 PM - 2 PM	1.2425	0.02013	1.1041	0.05445	2.38	YES
2 PM - 3 PM	1.2538	0.02011	1.1271	0.05600	2.13	YES
3 PM - 4PM	1.2664	0.02093	1.1527	0.05682	1.88	NO
4 PM - 5 PM	1.2848	0.02062	1.1716	0.05751	1.85	NO
5 PM - 6 PM	1.2954	0.02466	1.1840	0.05727	1.79	NO
6 PM - 7 PM	1.2703	0.02256	1.2008	0.05693	1.14	NO
7 PM - 8 PM	1.2558	0.02285	1.1982	0.05519	0.96	NO
8 PM - 9 PM	1.2454	0.02430	1.1714	0.05405	1.25	NO
9 PM - 10 PM	1.2061	0.02470	1.1336	0.05098	1.28	NO
10 PM - 11 PM	1.1665	0.02199	1.0832	0.04878	1.56	NO
11 PM - 12 Midnight	1.1503	0.01733	1.0556	0.04826	1.85	NO

Table 2-12
Comparison of Normalized Refrigerator Loads
PG&E AMP and SCE RAEUS
Winter Weekdays

Hour	SCE RAEUS		PG&E AMP		T - Ratio	Difference Significant at 95% Conf. Level
	Mean	Standard Error	Mean	Standard Error		
12 Midnight- 1 AM	0.8320	0.01890	0.8430	0.05717	-0.18	NO
1 AM - 2 AM	0.7992	0.01911	0.8094	0.05473	-0.18	NO
2 AM - 3 AM	0.7796	0.02126	0.7903	0.05027	-0.20	NO
3 AM - 4 AM	0.7670	0.02046	0.7684	0.04876	-0.03	NO
4 AM - 5 AM	0.7591	0.01995	0.7496	0.04556	0.19	NO
5 AM - 6 AM	0.7684	0.02146	0.7374	0.04421	0.63	NO
6 AM - 7 AM	0.7824	0.01953	0.7612	0.04810	0.41	NO
7 AM - 8 AM	0.8109	0.01663	0.8047	0.05040	0.12	NO
8 AM - 9 AM	0.8168	0.01880	0.8074	0.05166	0.17	NO
9 AM - 10 AM	0.8172	0.01760	0.8184	0.05431	-0.02	NO
10 AM - 11 AM	0.8158	0.01679	0.8528	0.05904	-0.60	NO
11 AM - 12 Noon	0.8526	0.01915	0.8812	0.06191	-0.44	NO
12 Noon - 1 PM	0.8880	0.01841	0.9145	0.06271	-0.41	NO
1 PM - 2 PM	0.8847	0.01675	0.9148	0.06449	-0.45	NO
2 PM - 3 PM	0.8954	0.01832	0.9170	0.06172	-0.34	NO
3 PM - 4PM	0.9140	0.01763	0.9375	0.06391	-0.35	NO
4 PM - 5 PM	0.9497	0.01826	0.9416	0.06591	0.12	NO
5 PM - 6 PM	0.9931	0.02125	0.9627	0.06135	0.47	NO
6 PM - 7 PM	1.0056	0.02028	0.9932	0.07117	0.17	NO
7 PM - 8 PM	0.9822	0.01804	0.9670	0.06193	0.24	NO
8 PM - 9 PM	0.9630	0.01817	0.9469	0.06548	0.24	NO
9 PM - 10 PM	0.9402	0.01898	0.9174	0.06276	0.35	NO
10 PM - 11 PM	0.8990	0.02021	0.9129	0.06551	-0.20	NO
11 PM - 12 Midnight	0.8627	0.01906	0.8889	0.06129	-0.41	NO

Table 2-13
Comparison of Normalized Refrigerator Loads
PG&E AMP and SCE RAEUS
Winter Weekends

Hour	SCE RAEUS		PG&E AMP		T - Ratio	Difference Significant at 95% Conf. Level
	Mean	Standard Error	Mean	Standard Error		
12 Midnight- 1 AM	0.8428	0.01837	0.8259	0.05818	0.28	NO
1 AM - 2 AM	0.8095	0.02059	0.8050	0.05157	0.08	NO
2 AM - 3 AM	0.7833	0.02024	0.7886	0.05574	-0.09	NO
3 AM - 4 AM	0.7665	0.02159	0.7755	0.05438	-0.15	NO
4 AM - 5 AM	0.7616	0.01985	0.7591	0.05105	0.05	NO
5 AM - 6 AM	0.7570	0.02224	0.7375	0.04762	0.37	NO
6 AM - 7 AM	0.7531	0.02052	0.7211	0.04769	0.62	NO
7 AM - 8 AM	0.7724	0.01677	0.7668	0.05308	0.10	NO
8 AM - 9 AM	0.8059	0.01805	0.7839	0.04624	0.44	NO
9 AM - 10 AM	0.8362	0.01784	0.8130	0.05235	0.42	NO
10 AM - 11 AM	0.8493	0.01567	0.8569	0.05179	-0.14	NO
11 AM - 12 Noon	0.8790	0.01820	0.8793	0.06110	-0.01	NO
12 Noon - 1 PM	0.9053	0.01946	0.9050	0.06234	0.01	NO
1 PM - 2 PM	0.9306	0.01982	0.9104	0.05527	0.34	NO
2 PM - 3 PM	0.9316	0.01980	0.9264	0.05782	0.08	NO
3 PM - 4PM	0.9475	0.01719	0.9236	0.05670	0.40	NO
4 PM - 5 PM	0.9690	0.01969	0.9409	0.06372	0.42	NO
5 PM - 6 PM	1.0139	0.02229	0.9479	0.06335	0.98	NO
6 PM - 7 PM	1.0001	0.02183	0.9641	0.06507	0.52	NO
7 PM - 8 PM	0.9850	0.02099	0.9602	0.06944	0.34	NO
8 PM - 9 PM	0.9604	0.02032	0.9393	0.06372	0.31	NO
9 PM - 10 PM	0.9289	0.01919	0.9055	0.05846	0.38	NO
10 PM - 11 PM	0.9070	0.01993	0.8954	0.06220	0.18	NO
11 PM - 12 Midnight	0.8717	0.01847	0.8957	0.06695	-0.35	NO

Table 2-14
Comparison of Normalized Refrigerator Loads
PG&E AMP and PG&E Efficient Refrigerators
Summer Weekdays

Hour	PG&E AMP		PG&E Eff. Ref.		T - Ratio	Difference Significant at 95% Conf. Level
	Mean	Standard Error	Mean	Standard Error		
12 Midnight- 1 AM	1.0024	0.04473	1.1412	0.00783	-3.06	YES
1 AM - 2 AM	0.9741	0.04328	1.0962	0.00762	-2.78	YES
2 AM - 3 AM	0.9486	0.04311	1.0631	0.00755	-2.61	YES
3 AM - 4 AM	0.9390	0.04277	1.0299	0.00730	-2.10	YES
4 AM - 5 AM	0.9137	0.04145	1.0171	0.00787	-2.45	YES
5 AM - 6 AM	0.8980	0.04016	1.0210	0.00783	-3.01	YES
6 AM - 7 AM	0.9286	0.04288	1.0452	0.00829	-2.67	YES
7 AM - 8 AM	0.9500	0.04292	1.0665	0.00769	-2.67	YES
8 AM - 9 AM	0.9478	0.04262	1.0674	0.00680	-2.77	YES
9 AM - 10 AM	0.9605	0.04469	1.0914	0.00776	-2.88	YES
10 AM - 11 AM	0.9851	0.04593	1.1259	0.00882	-3.01	YES
11 AM - 12 Noon	1.0346	0.05019	1.1785	0.00969	-2.81	YES
12 Noon - 1 PM	1.0702	0.05123	1.2167	0.01031	-2.80	YES
1 PM - 2 PM	1.0878	0.05304	1.2421	0.00977	-2.86	YES
2 PM - 3 PM	1.1085	0.05542	1.2767	0.01038	-2.98	YES
3 PM - 4PM	1.1330	0.05640	1.3146	0.01109	-3.16	YES
4 PM - 5 PM	1.1673	0.05802	1.3810	0.01198	-3.61	YES
5 PM - 6 PM	1.1945	0.05833	1.4331	0.01120	-4.02	YES
6 PM - 7 PM	1.2041	0.05733	1.4434	0.01068	-4.10	YES
7 PM - 8 PM	1.2016	0.05574	1.4108	0.01066	-3.69	YES
8 PM - 9 PM	1.1649	0.05332	1.3790	0.01026	-3.94	YES
9 PM - 10 PM	1.1352	0.05089	1.3264	0.00976	-3.69	YES
10 PM - 11 PM	1.0953	0.04880	1.2748	0.00985	-3.60	YES
11 PM - 12 Midnight	1.0577	0.04742	1.1998	0.00896	-2.94	YES

Table 2-15
Comparison of Normalized Refrigerator Loads
PG&E AMP and PG&E Efficient Refrigerators
Summer Weekends

Hour	PG&E AMP		PG&E Eff. Ref.		T - Ratio	Difference Significant at 95% Conf. Level
	Mean	Standard Error	Mean	Standard Error		
12 Midnight- 1 AM	1.0277	0.04578	1.1721	0.00917	-3.09	YES
1 AM - 2 AM	0.9726	0.04331	1.1260	0.00871	-3.47	YES
2 AM - 3 AM	0.9533	0.04346	1.0844	0.00850	-2.96	YES
3 AM - 4 AM	0.9428	0.04292	1.0503	0.00824	-2.46	YES
4 AM - 5 AM	0.9126	0.04146	1.0234	0.00857	-2.62	YES
5 AM - 6 AM	0.8912	0.04007	1.0128	0.00824	-2.97	YES
6 AM - 7 AM	0.9036	0.04110	1.0143	0.00780	-2.65	YES
7 AM - 8 AM	0.9213	0.04187	1.0557	0.00831	-3.15	YES
8 AM - 9 AM	0.9469	0.04339	1.0998	0.00825	-3.46	YES
9 AM - 10 AM	0.9867	0.04660	1.1501	0.00959	-3.43	YES
10 AM - 11 AM	1.0026	0.04629	1.2067	0.01014	-4.31	YES
11 AM - 12 Noon	1.0462	0.04979	1.2560	0.01089	-4.12	YES
12 Noon - 1 PM	1.0851	0.05139	1.2910	0.01079	-3.92	YES
1 PM - 2 PM	1.1041	0.05445	1.3288	0.01190	-4.03	YES
2 PM - 3 PM	1.1271	0.05600	1.3603	0.01135	-4.08	YES
3 PM - 4PM	1.1527	0.05682	1.3903	0.01166	-4.10	YES
4 PM - 5 PM	1.1716	0.05751	1.4211	0.01222	-4.24	YES
5 PM - 6 PM	1.1840	0.05727	1.4566	0.01216	-4.66	YES
6 PM - 7 PM	1.2008	0.05693	1.4522	0.01246	-4.31	YES
7 PM - 8 PM	1.1982	0.05519	1.4389	0.01180	-4.27	YES
8 PM - 9 PM	1.1714	0.05405	1.4193	0.01170	-4.48	YES
9 PM - 10 PM	1.1336	0.05098	1.3686	0.01129	-4.50	YES
10 PM - 11 PM	1.0832	0.04878	1.3059	0.01110	-4.45	YES
11 PM - 12 Midnight	1.0556	0.04826	1.2400	0.01064	-3.73	YES

Table 2-16
Comparison of Normalized Refrigerator Loads
PG&E AMP and PG&E Efficient Refrigerators
Winter Weekdays

Hour	PG&E AMP		PG&E Eff. Ref.		T - Ratio	Difference Significant at 95% Conf. Level
	Mean	Standard Error	Mean	Standard Error		
12 Midnight- 1 AM	0.8430	0.05717	0.8200	0.00676	0.40	NO
1 AM - 2 AM	0.8094	0.05473	0.7922	0.00673	0.31	NO
2 AM - 3 AM	0.7903	0.05027	0.7694	0.00651	0.41	NO
3 AM - 4 AM	0.7684	0.04876	0.7526	0.00681	0.32	NO
4 AM - 5 AM	0.7496	0.04556	0.7412	0.00699	0.18	NO
5 AM - 6 AM	0.7374	0.04421	0.7439	0.00718	-0.14	NO
6 AM - 7 AM	0.7612	0.04810	0.7756	0.00870	-0.29	NO
7 AM - 8 AM	0.8047	0.05040	0.8100	0.00862	-0.11	NO
8 AM - 9 AM	0.8074	0.05166	0.8081	0.00776	-0.01	NO
9 AM - 10 AM	0.8184	0.05431	0.8076	0.00715	0.20	NO
10 AM - 11 AM	0.8528	0.05904	0.8133	0.00710	0.67	NO
11 AM - 12 Noon	0.8812	0.06191	0.8326	0.00746	0.78	NO
12 Noon - 1 PM	0.9145	0.06271	0.8656	0.00747	0.78	NO
1 PM - 2 PM	0.9148	0.06449	0.8600	0.00689	0.85	NO
2 PM - 3 PM	0.9170	0.06172	0.8646	0.00661	0.84	NO
3 PM - 4PM	0.9375	0.06391	0.8834	0.00702	0.84	NO
4 PM - 5 PM	0.9416	0.06591	0.9141	0.00812	0.41	NO
5 PM - 6 PM	0.9627	0.06135	0.9629	0.00884	-0.00	NO
6 PM - 7 PM	0.9932	0.07117	0.9971	0.00950	-0.05	NO
7 PM - 8 PM	0.9670	0.06193	0.9854	0.00899	-0.29	NO
8 PM - 9 PM	0.9469	0.06548	0.9656	0.00883	-0.28	NO
9 PM - 10 PM	0.9174	0.06276	0.9409	0.00818	-0.37	NO
10 PM - 11 PM	0.9129	0.06551	0.9061	0.00776	0.10	NO
11 PM - 12 Midnight	0.8889	0.06129	0.8574	0.00716	0.51	NO

Table 2-17
Comparison of Normalized Refrigerator Loads
PG&E AMP and PG&E Efficient Refrigerators
Winter Weekends

Hour	PG&E AMP		PG&E Eff. Ref.		T - Ratio	Difference Significant at 95% Conf. Level
	Mean	Standard Error	Mean	Standard Error		
12 Midnight- 1 AM	0.8259	0.05818	0.8171	0.00774	0.15	NO
1 AM - 2 AM	0.8050	0.05157	0.7869	0.00721	0.35	NO
2 AM - 3 AM	0.7886	0.05574	0.7609	0.00711	0.49	NO
3 AM - 4 AM	0.7755	0.05438	0.7444	0.00715	0.57	NO
4 AM - 5 AM	0.7591	0.05105	0.7352	0.00734	0.46	NO
5 AM - 6 AM	0.7375	0.04762	0.7238	0.00721	0.28	NO
6 AM - 7 AM	0.7211	0.04769	0.7238	0.00794	-0.06	NO
7 AM - 8 AM	0.7668	0.05308	0.7508	0.00802	0.30	NO
8 AM - 9 AM	0.7839	0.04624	0.7932	0.00843	-0.20	NO
9 AM - 10 AM	0.8130	0.05235	0.8286	0.00838	-0.29	NO
10 AM - 11 AM	0.8569	0.05179	0.8436	0.00793	0.25	NO
11 AM - 12 Noon	0.8793	0.06110	0.8728	0.00778	0.11	NO
12 Noon - 1 PM	0.9050	0.06234	0.9048	0.00863	0.00	NO
1 PM - 2 PM	0.9104	0.05527	0.9115	0.00797	-0.02	NO
2 PM - 3 PM	0.9264	0.05782	0.9139	0.00783	0.22	NO
3 PM - 4PM	0.9236	0.05670	0.9252	0.00719	-0.03	NO
4 PM - 5 PM	0.9409	0.06372	0.9402	0.00817	0.01	NO
5 PM - 6 PM	0.9479	0.06335	0.9795	0.00916	-0.49	NO
6 PM - 7 PM	0.9641	0.06507	1.0034	0.01014	-0.60	NO
7 PM - 8 PM	0.9602	0.06944	0.9877	0.01025	-0.39	NO
8 PM - 9 PM	0.9393	0.06372	0.9689	0.00963	-0.46	NO
9 PM - 10 PM	0.9055	0.05846	0.9328	0.00905	-0.46	NO
10 PM - 11 PM	0.8954	0.06220	0.9013	0.00808	-0.09	NO
11 PM - 12 Midnight	0.8957	0.06695	0.8606	0.00767	0.52	NO

SECTION 3: ASSESSMENT OF REFRIGERATOR SALES AND SHIPMENT DATA

This section presents a discussion of the usefulness of refrigerator sales or wholesale shipment data as a possible basis for estimating the key parameters associated with the energy impacts of refrigerator incentive programs. The calculation of program impacts using sales and shipment data is a formidable task. However, these calculations have been carried out at a utility service territory level (see HBRS, Inc. and Barakat and Chamberlin, Inc., 1992; SDG&E, 1992)[1] and could potentially be expanded to cover other utilities or a state level analysis. Calculations of these impacts involve a number of tasks. No single source of sales and/or shipment data provide all the information needed to compute net-to-gross ratios or to estimate other program effects, such as rebound or spillover. The basic impact parameters that could potentially be measured with sales and shipment data are briefly described below:

Net Program Impacts. The calculation of net program impacts would involve an estimate of (1) the annual kWh savings over the 1993 Federal Appliance Efficiency Standard for the average refrigerator sold in a specific utility service area and/or the entire state of California and (2) the annual kWh savings over the 1993 Federal Appliance Efficiency Standard for the average refrigerator sold in a comparison area (either other regions or the U.S. as a whole). The difference between these two averages would provide an estimate of the net program impact per refrigerator sold in a specific utility service area and/or the entire state of California. This net program impact per refrigerator would then be multiplied by the estimated total number of refrigerators sold in a utility service area or state. This would produce the total net program estimated savings for the given utility or for the state.

Free-riders and Naturally Occurring Conservation. The calculation of the impact of free-riders and naturally occurring conservation taking place in the refrigerator market could also be estimated using sales data. Naturally occurring conservation could be calculated by comparing the average annual kWh usage for an average-size refrigerator in the comparison area with the consumption of the same average refrigerator based on the 1993 Federal Appliance Efficiency Standard. This annual kWh savings would become an estimate of what the per-unit savings over the 1993 Federal Appliance Efficiency Standards would have been in the absence of utility incentive programs. This per-unit information could then be used to estimate the impact of free-riders in a given utility's service area. The term free-rider generally refers to utility customers who participate in a rebate program who would have purchased an energy-efficient refrigerator (i.e., rebate-qualifying refrigerator) without receiving a utility incentive. This calculation would involve multiplying the number of units sold in a service area or state by the average efficiency improvement over the federal standard for refrigerators sold outside of California. This calculation implicitly assumes that the California programs have no effect on the efficiencies of the units sold in the comparison area. The reasonableness of this assumption could be investigated by interviewing refrigerator manufacturers to determine whether the California programs influence them at the national level.

Gross Program Impacts. Gross program impacts could be calculated by simply adding the impact of program free-riders to the net program impact. However, similar to the above discussion concerning free-riders, the importance of calculating gross program impacts may need to be revisited. This is primarily due to the fact that sales and shipment data most easily lend themselves to the calculation of net program impacts. Net program impacts have traditionally been the objective of most impact evaluation efforts.

Free-driver and Spillover. The term free-driver commonly refers to customers who participate in a utility demand-side management program who go on to purchase other energy-efficient equipment in the absence of a utility incentive. Spillover refers to customers who purchase rebate-qualifying refrigerators without receiving a direct utility incentive. Spillover would also include those purchasers (e.g., program nonparticipants) who buy more energy-efficient refrigerators (not necessarily qualifying units) than they would have in the absence of utility rebate programs. This impact often occurs because utility programs and/or the combination of programs change the distribution of efficiencies available. Calculation of the spillover effects of refrigerator rebate programs would involve calculating the efficiency improvement of each rebated refrigerator over the 1993 Federal Appliance Efficiency Standard and totaling the savings for each utility program and across programs. This impact could then be subtracted from the adjusted gross program impact in order to estimate the overall savings attributable to spillover. The adjusted gross program impact refers to the calculation of the average annual kWh savings of a refrigerator sold in a utility service area or the state over the 1993 Federal Appliance Efficiency Standard times the number of units sold in the area of interest.

Rebound. In the refrigerator market, the rebound effect is usually discussed in the context of whether or not rebate programs are causing customers to purchase refrigerators that are larger and/or have more features than they would have purchased in the absence of the program. Additionally, the extent to which customers increase the number of refrigerators they have as a result of rebate programs and the energy use associated with these units contribute to this effect. Sales and shipment data by brand name and model number allow for the determination of a refrigerator's basic size and features. As a result, sales and shipment data could potentially provide important insight into the rebound effect of refrigerator rebate programs. However, sales and shipment data would not be able to provide information on the extent to which customers actually increase their energy use because of the rebate program through higher propensities to keep existing refrigerators.

DESCRIPTION OF AVAILABLE SALES AND SHIPMENT DATA

Refrigerator sales and/or shipment data that could potentially be used in calculating these impact parameters are available from a number of sources. These sources include the Association of Home Appliance Manufacturers, distributors, retailers, and consumers. The data available from each of these data sources are described below.

Association of Home Appliance Manufacturers (AHAM). AHAM collects refrigerator shipment data from manufacturers on both a monthly and an annual basis. Each of these independent data collection efforts are described in more detail below.

Monthly County Data. On a monthly basis, AHAM receives the number of refrigerators shipped by manufacturers to various counties throughout the United States. AHAM is continually trying to improve upon the quality of the shipment data it receives. The major problem with the data submitted by manufacturers is that many manufacturers do not have records of what happens to a refrigerator after it arrives at the initial shipping point (typically a distributor or a major retailer distribution center). As a result, manufacturers rely on data supplied to them by distributors and major retailers on where the actual refrigerators end up. Many distributors estimate their shipments at a county level because they are either unwilling or unable to give detailed information. It is important to remember that these data are simply numerical counts by county and do not contain information regarding the efficiency level of the refrigerators shipped. This information has been purchased by the California Energy Commission in the past.

Annual Efficiency Data. On an annual basis, AHAM collects information from each manufacturer via a survey instrument that reports the number of units shipped by the manufacturer in the past year and what their basic efficiency level was. This information has been purchased by Pacific Gas and Electric in the past. This information is provided to AHAM for all units shipped, and it is not broken down by any geographical area. Additionally, there is no link between this type of data and the data that are provided on a monthly basis for each county. AHAM does not currently have the ability to report shipment data by efficiency level at any geographical level of precision other than the entire United States.

The primary problem that AHAM has with supplying either monthly or annual shipment data by county and efficiency level is the ability of manufacturers to track their own refrigerator shipments to specific areas of the United States. AHAM and manufacturers are currently grappling with how to design systems that will supply this information. This is especially problematic given the fact that most manufacturers have to rely upon major purchasers (e.g., distributors and major retailers) to tell them where the refrigerators are ultimately shipped.

AHAM has a Refrigerator Council who would have to approve of any efforts to have manufacturers work toward supplying county-level shipment data by efficiency level. If approved by the council, it would have to be approved by the AHAM Board of Directors. After both of these steps, it would be up to the individual manufacturers to decide whether or not they wanted to make the effort to design a system that would provide this type of information.

Distributors. A second source of sales data is the refrigerator distributor. Distributors may also have sales data by brand name and model number, although these data may lack the level of geographical precision necessary for estimating key impact parameters. However, refrigerator trade ally studies have revealed that the role of "traditional distributors" in the refrigerator distribution channel is declining (see HBRS, Inc., WCDSR-111-1).[2] National retailers and the majority of large regional retailers purchase their refrigerators directly from the manufacturer. Although the combined market share of the national retailers and regional retailers in California is not known with certainty, it probably exceeds 50 percent of all units sold in California (see HBRS, Inc. and Barakat and Chamberlin, Inc., 1992).[3] It also appears that large, nonregional retailers may also be purchasing units directly from manufacturers. As a result, any data collection effort targeted toward the distributor level is likely to collect shipment information for only a limited set of the total refrigerator market. The shipment data received would most likely represent purchases of multiple-establishment stores that serve a fairly small geographical area (e.g., a city, county, or multiple counties) and single-establishment stores.

Retailers. A third source of sales data is retailers. A number of past studies have found that the majority of refrigerator retailers have refrigerator sales data available by brand name and model number (see HBRS, Inc. and Barakat and Chamberlin, Inc., 1992; Russell Brooker, 1989; WP&L, 1986; WP&L, 1988; and Antoinette Tobin, 1986).[4] A study conducted for Pacific Gas and Electric Company (PG&E) obtained store-level sales data by brand name and model number for PG&E's service territory for two of three national retailers. These national retailers, combined with other retailers, provided sales information for over 53,000 refrigerators in PG&E's service territory and over 150,000 refrigerators outside of PG&E's service territory (see HBRS, Inc. and Barakat and Chamberlin, Inc., 1992).[5] The national retailer who did not cooperate in the PG&E study was also reported to have brand name and model number information available at the store-level. Although the cooperation rate among regional retailers, multi-establishment, and single-establishment firms has varied across studies, very few retailers indicated that they simply do not have sales information by brand name and model number available in any form.

Consumers. A fourth source of refrigerator sales data is the collection of sales data directly from residential customers. This process would involve telephone surveys of residential customers to screen for recent refrigerator purchasers. These purchasers would then be instructed to look inside the fresh-food compartment of their new refrigerator and record the brand name and model number information. This approach can provide a representative sample of purchasers at very detailed levels of geographic precision.

USEFULNESS OF AVAILABLE SALES AND SHIPMENT DATA IN ESTIMATING NET-TO-GROSS RATIOS

This section will briefly discuss the usefulness of each of the approaches to collecting sales and/or shipment data in estimating the net-to-gross ratios of refrigerator programs' impacts. The strengths and weaknesses of each approach will be discussed, as well as the possibility of combining approaches in order to estimate program impacts.

AHAM. The major drawback with the AHAM data that are either currently available or have been purchased in the past is a lack of geographical precision. AHAM can only provide refrigerator weighted average efficiency information at the national level. This information is gathered through annual surveys of refrigerator manufacturers. Although AHAM collects monthly shipment data at the county level, this is simply a numerical count of units shipped.

The AHAM information, taken alone, does not appear to be a useful method of estimating net-to-gross ratios for refrigerator rebate programs in California. However, the information from AHAM's annual survey of refrigerator manufacturers (e.g., annual shipment-weighted efficiency information) can provide a useful benchmark (i.e., comparison area) against which to compare California-specific information. The major drawback of using AHAM annual shipment-weighted data as a comparison area is that these data include shipments to California.

Distributors. The collection of refrigerator shipment data from distributors has a number of major limitations. First, as previously mentioned, all three national retailers and many regional retailers do not purchase refrigerators from distributors. Most of these organizations purchase refrigerators direct from refrigerator manufacturers. Second, although distributors have been approached about their sales data in some studies (see HBRS, Inc., WCDSR-111-1 and WCDSR 110-1)[6], it is uncertain whether they have the information in a format that would be useful (e.g., by brand name and model number). Third, many distributors sell across a numbers of counties and/or states and may not specifically track brand names and model number to a retail store level.

Any distributor shipment information, taken alone, is unlikely to be representative of all refrigerator sales because most refrigerators do not pass through distributors. There may, however, be some potential for using distributor information as a supplement to other data collection efforts.

Retailers. The collection of refrigerator sales data at the retail level appears to hold the most promise for providing useful estimates of program impacts. National retailers, multiple-establishment stores, and single-establishment stores have been generally cooperative in past studies sponsored by large utilities. Discussions with the Electric and Gas Industry Association of California, the California Energy Commission, and key national retailers indicate that this approach may very well be successful. A coordinated effort sponsored by the California Energy Commission and the major investor-owned utilities in the state would help to pressure retailers to cooperate. Retailers generally have sales data available by brand name and model number. This is the level of precision needed to estimate net-to-gross ratios. Brand name and model number information for each refrigerator sold allows for the computation of each refrigerator's 1993 Federal Appliance Efficiency Standard, as well as the refrigerator's percentage improvement in efficiency over the standard.

The major weakness of past refrigerator sales data collection efforts directed at the retailer and/or distributor level has been the lack of cooperation of major regional retailers. A study sponsored by the Wisconsin Center for Demand-Side Research (WCDSR) revealed that across almost all refrigerator sales tracking efforts undertaken to date, a considerable number of major regional retailers (i.e., regional chains) refused to provide their sales data (see HBRS, Inc., 1993).[7] This lack of cooperation leads to questions regarding the representativeness of the data that are collected.

Consumers. A random-digit-dial (RDD) approach to identifying purchasers of refrigerators also appears to have some merit. This approach has the potential to generate a representative sample of purchasers at very detailed levels of geographic precision. It also gives the researcher the ability to collect other information on household equipment holdings and related demographic information that provide important insight into purchasing behavior. Past studies sponsored by PG&E and the WCDSR have been able to collect brand name and model number information from approximately 70 percent of the purchasers identified (see HBRS, Inc., 1993).[8] However, similar to retail data collection procedures that do not secure the participation of all retailers contacted, some purchasers will decide not to cooperate. As a result, there will always be concerns with the representativeness of the data collected.

Although there are very few methods of checking the representativeness of the sales data collected from retailers, there is at least one method of checking the representativeness of a random-digit-dial sample if basic demographic information is collected. This process involves a comparison of the demographic information collected through the RDD process to census data for a geographical area and/or entire state. In this way, one can determine whether or not the RDD dial effort was successful in gaining the participation of households with various characteristics. For example, it could be determined whether renters are over- or under-represented in the RDD sample compared to census data. Theoretically, one could correct for these differences by weighting the data to correct for any over- or under-representation.

SUMMARY AND CONCLUSIONS

The calculation of gross program savings, net program savings, free-riders, and free-drivers is a formidable task. However, these calculations can be done at both a utility service territory and state level. As previously mentioned, the calculation of these impacts would involve many detailed tasks and no single source of sales and/or shipment data will provide all the information needed to compute net-to-gross ratios and to estimate other program effects, such as free-riders and free-drivers. However, an approach that uses various combinations of data has considerable promise.

Retail-level sales data at the store level can provide both the geographical precision and efficiency data necessary to estimate the distribution of efficiencies by utility service area and for the entire state of California. A random-digit-dial approach could also be used to provide this information with the necessary geographical precision. This random-digit-dial approach could be used exclusively or it could be used as a method of checking the representativeness of the sales data collected through a retail approach. Finally, data provided by major retailers for comparison areas outside of California as well as AHAM national shipment weighted data could provide the necessary "control" areas. This triangulation (i.e., retail-level data, random-digit-dial data, AHAM data) in combination with other information currently collected by utilities (e.g., appliance saturation surveys) and the California Energy Commission (e.g., county-level shipment data purchased from AHAM) will allow for net-to-gross ratio calculations and estimates of free-riders and free-drivers at both a utility service area and state level.

This approach is not without its limitations. The most significant limitation is the fact that cooperation rates among major national and regional retailers cannot be guaranteed. However, the combined influence of the California Energy Commission and the major investor-owned utilities should have a considerable impact on these retailers. Additionally, a random-digit-dial effort undertaken at the same time would provide supplementary information so that the evaluation was not dependent on a single source for data collection.

1. HBRS, Inc. and Barakat and Chamberlin, Inc., "*Impact Report--Evaluation of the Refrigerator Incentive Programs*," Prepared for Pacific Gas and Electric Company, November 1992.

   SDG&E. Boutwell, Bob and Don Wiggins, Residential High Efficiency Refrigerator Report, December 1992.

2. HBRS, Inc., *Utility Programs and the Distribution of Residential Appliances: A Qualitative Study*, Prepared for the Wisconsin Center for Demand-Side Research, WCDSR-111-1.

   HBRS, Inc., *Utility Programs and the Distribution of Residential Appliances: A Literature Review*, Wisconsin Center for Demand-Side Research, WCDSR-111-1.

3. HBRS, Inc. and Barakat and Chamberlin, Inc., "*Impact Report--Evaluation of the Refrigerator Incentive Programs*," Prepared for Pacific Gas and Electric, November 1992.

4. HBRS, Inc. and Barakat and Chamberlin, Inc., "*Impact Report--Evaluation of the Refrigerator Incentive Programs*," Prepared for Pacific Gas and Electric, November 1992.

   Russell G. Brooker, Ph.D. (Wisconsin Electric Company), "Testing the Effectiveness of a Residential Rebate Program by Tracking Sales of Appliances Inside and Outside the Utility's Territory: The Case of Wisconsin Electric's 1988 Smart Money Program," *Energy Program Evaluation: Conservation and Resource Management*, The Fourth International Conference, Chicago, IL, 1989, p. 257-262.

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Antionette Tobin, "*Evaluation of the NYSEG Power Pincher Refrigerator Rebate Program--1986*," New York State Electric and Gas.

5. HBRS, Inc. and Barakat and Chamberlin, Inc., "*Impact Report--Evaluation of the Refrigerator Incentive Programs*," Prepared for Pacific Gas and Electric Company, November 1992.

6. HBRS, Inc., "*Utility Programs and the Distribution of Residential Appliances: A Qualitative Study*," Prepared for the Wisconsin Center for Demand-Side Research, WCDSR-111-1.

   HBRS, Inc., "*Utility Programs and the Distribution of Residential Appliances: A Literature Review*," Wisconsin Center for Demand-Side Research, WCDSR 110-1.

7. HBRS, Inc., "*Requirements for a Sales Tracking System: A Scoping Study*," Wisconsin Center for Demand-Side Research, 1993.

8. HBRS, Inc., *Summary of Appliance Sales Tracking Pilot Study (Wave #1)*, Wisconsin Center for Demand-Side Research, June 1993.

   HBRS, Inc. and Barakat and Chamberlin, Inc., *Impact Report--Evaluation of Refrigerator Incentive Programs*, Prepared for Pacific Gas and Electric Company, November 1993.

SECTION 4: REVIEW OF ESTIMATES OF USEFUL LIFE

This section presents a discussion of the existing assumptions used to estimate refrigerator useful life and the data and methods used to support these assumptions. The useful life of a refrigerator is a key component of the energy savings calculations used to estimate the impact of refrigerator incentive programs. The savings attributed to a particular program for the immediate program year is often multiplied by the useful life estimate in order to derive the total program-induced savings over the life of the measure. As a result, the life of the measure (e.g., refrigerator) has a considerable impact on the overall program-induced savings estimate.

DEFINITION(S) OF USEFUL LIFE

Effective useful life, engineering useful life, and operational life are often referred to in discussions about the life of demand-side management measures. For this report, the definitions used for the DSM Measure Life Project sponsored by the California DSM Measurement Advisory Committee (CADMAC) will be used. The following definitions and accompanying discussion can be found in the DSM Measure Life Project Final Report (see CADMAC, 1993).[1] These definitions are as follows:

> **Effective Useful Life.** This term was defined by the collaborative as "an estimate of the number of years that a piece of equipment will operate if properly maintained, adjusted for early removal that would have happened in the absence of the program." This definition was interpreted by the CADMAC Persistence Subcommittee to mean that effective useful life estimates can be quantitatively derived as the elapsed number of years between the installation of a cohort of measures in a given program year and the time when 50 percent of those measures have either been removed or cease to operate in the building environment in which they were originally installed. Determination of effective useful life of DSM measures requires taking into account remodeling, customer dissatisfaction, and other behavioral conditions that lead to removal of measures prior to their actual "burn-out."
>
> **Engineering Useful Life.** Defined by the collaborative as "an estimate of the number of years that a piece of equipment will operate if properly maintained." Engineering useful life is typically determined in a laboratory setting and, as a consequence, does not account either for early removal of the equipment or field use realities, such as breakage. This lifetime is usually estimated by the equipment manufacturer.
>
> **Operational Life.** Operational life is also referred to as "service life." Operational life is defined as the average lifetime of a measure under typical operating conditions and average maintenance practices (non-laboratory conditions). Operational useful life estimates do not account for early removal but do account for field use realities, such as breakage. Estimates of operational life or service life are often found in sources such as ASHRAE journals.

This section is primarily concerned with utility efforts and methods for estimating effective useful life. Effective useful life is the most appropriate measure to use for estimating the impact of demand-side management programs because it accounts for early removal and breakage. Engineering useful life or operational life estimates both overstate demand-side management program savings because (1) neither accounts for early removal and because (2) engineering useful life also does not account for field use realities such as breakage.

CURRENT USEFUL LIFE ESTIMATES

Consistent with the findings of the DSM Measure Life Project[5], findings from this study also indicate that estimates of effective useful life used by various California utilities differ across utilities. As found in the HBRS review of existing methods and data sources (see CADMAC, 1993)[2] (Section 1 of this study), both Pacific Gas and Electric (PG&E) and San Diego Gas and Electric (SDG&E) use a 20-year effective useful life in their refrigerator program planning methods and assumptions. This effective useful life is based on the 1990/91 collaborative agreement. Under this agreement, both utilities negotiated estimates of appliance lives that were acceptable to all parties. Southern California Edison (SCE) also uses a negotiated effective useful life estimate. This effective life of 18 years was directly negotiated with the California Energy Commission.

The data sources typically available to help inform effective useful life estimates include the following types:

> **Residential Appliance Saturation Surveys.** These surveys, which are conducted periodically by California utilities, ask a sample of residential customers a series of demographic and equipment-holding questions, including the size, age and other relevant features of their current refrigerators. The average age of second refrigerators is often used as a proxy for the effective useful life of a refrigerator. The assumption is that the average age of second refrigerators approximates the amount of time when 50 percent of the refrigerators manufactured and sold in a given year are still in operation and the other 50 percent are retired. A study completed for Pacific Gas and Electric revealed that the average age of second refrigerators as reported by survey respondents was 16.9 years (see PG&E, 1993).[3] A San Diego Gas and Electric study revealed an average age of 11.6 years for second refrigerators (see SDG&E, 1993).[4]
>
> For a number of reasons, however, average age does not necessarily indicate effective useful life. First, these second refrigerators are still operating and have not reached the end of their useful life. Therefore, their average age does not reflect their entire useful life. Second, average age may not necessarily correlate with the elapsed time between the installation of refrigerators in a given program year and the time when 50 percent of those refrigerators are no longer

5 Ibid., p.5.

operating in a utility service area. Third, appliance age information obtained through customer self-reports can be inaccurate. For example, in an October 1993 conversation, Planergy estimated that only about one-half of the participants in Niagara Mohawk's Refrigerator Roundup™ Program were able to correctly report the actual age of their second refrigerators.

Refrigerator Incentive Program Evaluations. Information collected as part of refrigerator incentive program evaluations are also used to inform useful effective life estimates. Many refrigerator program evaluations across the U.S. have asked participating customers the age of the refrigerators they replaced. An evaluation of PG&E's refrigerator incentive programs revealed that the average age of replaced refrigerators was reported to be between 14.3 and 14.8 years (see PG&E, 1992).[5] A few studies have also asked customers detailed questions about the ultimate disposition of replaced refrigerators. Typical customer reports included selling the replaced refrigerator to a friend or relative, having the refrigerator removed by a refrigerator dealer or the utility, junking the refrigerator themselves, junking the refrigerator through a local government appliance pick-up program, and moving the refrigerator to the basement or garage.

Refrigerator Turn-in Programs. Refrigerator turn-in programs are currently operating in a number of areas the U.S.[6] However, most of these programs do not attempt to formally measure the age of refrigerators being junked. The typical emphasis is on estimating the savings realized by removing an old refrigerator and refrigerator age is of secondary interest (see Home Energy Magazine, January/February 1993). Determining the age of a refrigerator can be a difficult task. A number of sophisticated techniques based on an understanding of refrigerator manufacturers and the history of refrigerator production have been developed. Planergy, through their work with Niagara Mohawk and other utilities, has developed a useful and reliable method for determining the age of the refrigerators they remove from residences. Based on customer survey results, the weighted average age of all junked refrigerators picked up through Niagara Mohawk's 1991 Refrigerator Roundup™ Program was 24.6 years (see Niagara Mohawk Power Corporation, 1992).[6] Results of the 1992 evaluation, which was expanded beyond the Syracuse area, revealed an estimated average age for junked refrigerators of 32 years (see Niagara Mohawk Power Corporation, 1993).[7]

Engineering Useful Life Estimates. These estimates are typically used to set an upper bound on the effective useful life of refrigerators. Engineering useful life is typically determined in a laboratory setting by the refrigerator manufacturer. These estimates do not take many relevant factors into account. For example, the frequency of early refrigerator removal and breakdowns are not included in engineering useful life estimates.

Operational Life. These estimates are used to set a somewhat modified upper bound on effective useful life. While operational useful life estimates take refrigerator breakdown rates into account they do not account for early removals. As a result, operation life is also likely to overstate the actual effective useful life of a refrigerator. Estimates of operational life or service life can be found in sources such as ASHRAE journals.

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[6]Some of the utilities currently running turn-in programs include Consumers Power Company, Dayton Power and Light, Ohio Edison, Massachusetts Electric, PEPCO, Sacramento Municipal Utility District, Niagara Mohawk Power Corporation, Toledo Edison, and Wisconsin Electric Power Company.

PAST USEFUL LIFE STUDIES

Consistent with the findings from the DSM Measure Life Project, no specific field studies of refrigerator useful life were found through this review. The DSM Measure Life Project also found that the "confidence in current measure life estimates was not particularly high" (see CADMAC, 1993).[8] Both the measure life project and this review found that utility program planners do not, however, believe their estimates are wrong or without support. This is primarily due to the fact that the estimates are at least in part based upon information collected through residential appliance saturation surveys, refrigerator rebate program evaluations, and manufacturer estimates of engineering life and/or operational life. However, because no formal studies of refrigerator effective useful life have been completed to date, a moderate level of uncertainty exists associated with the current estimates.

REFRIGERATOR USEFUL LIFE ISSUES

As previously described, effective useful life is an estimate of the number of years a piece of equipment will operate if properly maintained, adjusted for early removal that would have happened in the absence of the program. Refrigerator effective useful life is an aggregate concept and should be based upon the point in time when 50 percent of the refrigerators manufactured and sold in a given year are still in operation and the other 50 percent are retired. Two issues discussed below are important for determining refrigerator effective useful life: the difficulty of determining the age of individual refrigerators and the problems associated with using useful life estimates of old refrigerators to represent the new generation of refrigerators.

Although refrigerator effective useful life is an aggregate concept, individual assessments of specific refrigerator lives must be made. Many questions arise when determining the effective useful life of specific refrigerators. For example, if a refrigerator is moved from one household within a service territory to another in the same territory, should the age at removal be considered the end of the refrigerator's effective useful life? Or should the effective useful life of a refrigerator be defined as the age at which the refrigerator is junked? If a refrigerator is moved from one utility service territory to another territory or to another country (e.g., Mexico) should the age at transfer be considered the end of the refrigerator's useful life? If a refrigerator dealer reconditions and resells a refrigerator, does this extend the effective useful life of the refrigerator? How does one account for refrigerators that are moved into a utility's service area through reconditioning programs or through new households moving into the territory and bringing their old refrigerators with them?

In answer to the above questions, refrigerator effective useful life should not be measured by the age at which the refrigerator was removed from a household unless the refrigerator was (1) junked or (2) moved out of the utility's service territory. The remaining refrigerator removal scenarios described above should not be used because they are not specifically associated with the end of a refrigerator's useful life. For instance, a refrigerator removed from a household within a utility's service territory and installed in another household within the same territory should not be considered at the end of its useful life when removed. Similarly, refrigerators that are reconditioned and/or resold in the same utility service area should not be considered at the end of their useful lives. Instead, useful life measurements should consist of an appropriately weighted mix of the ages of junked refrigerators and the ages of refrigerators removed from a utility service territory (e.g., reconditioned and/or resold in other territories or countries).

A second important issue regarding refrigerator useful life is whether useful life estimates based upon the ages of currently disposed of refrigerators is representative of the effective useful life of new refrigerators. New refrigerators vary significantly from older refrigerators in construction and features. Construction materials (e.g., refrigerator side-walls, temperature controls, insulation, etc.) and features (e.g., through-the-door water, automatic ice makers, etc.) have changed over the past 10 to 15 years. Manufacturers have also improved their automatic defrost technologies. The impact of these new features on the effective useful life of refrigerators is not known. For the newest generations of refrigerators, it may be inappropriate to use effective useful life estimates that have been based on older refrigerators.

POTENTIAL IMPROVEMENTS TO EFFECTIVE USEFUL LIFE MEASUREMENTS

A number of potential approaches could be used to improve estimates of the effective useful life of refrigerators. Many of these approaches simply expand the ones that are currently being used.

Survey Techniques. This approach involves surveying both customers who purchased refrigerators through demand-side management programs and customers who purchased refrigerators outside of demand-side management programs (i.e., nonparticipants). All purchasers would be asked detailed questions about the age and disposition of their old refrigerator. The ultimate goal of this exercise would be to determine the age distribution of all refrigerators that were junked or moved out of the utility's service territory.

Recycling Centers. Recycling centers are a potential source of information on the age distribution of junked refrigerators. Presumably, these centers receive shipments of refrigerators periodically. A process could potentially be established where these recycling centers are paid to assist in the determination of the ages of these discarded refrigerators.

Refrigerator Turn-in Programs. Many refrigerator turn-in programs currently being offered do not formally attempt to determine the ages of refrigerators that are turned in. This could be a valuable source of information about effective useful life of refrigerators. The cost of this additional activity would be relatively small compared to the overall cost of the turn-in program.

SUMMARY AND RECOMMENDED APPROACH

Formal studies geared toward the estimation of refrigerator effective useful life are currently lacking. However, a number of current data collection mechanisms could be expanded to include the collection of information that would provide additional insight into refrigerator useful life. No one data collection method will provide a complete picture of refrigerator useful life. However, a combination of approaches appears to be both relevant and feasible.

Current survey data collection techniques implemented as part of refrigerator program evaluations could be expanded to more clearly and concisely track replaced refrigerators. This would involve contacting a random sample of residential customers in order to identify those who disposed of a refrigerator in the last year. Determining who the refrigerator was given to would be a key variable of interest. Those most likely to have picked up the replaced refrigerators include refrigerator dealers, utility turn-in programs, and municipal appliance disposal programs. Replaced refrigerators could also have been given to or sold to another individual, moved to the basement or garage, or moved to another residence, such as a cottage. Additional survey follow-up would then be needed to find out what the second parties did with the refrigerator. Presumably, most utility turn-in programs result in the refrigerators being disposed of in an environmentally safe manner. However, it is not clear what dealers, municipalities, and other related businesses do with the refrigerators they pick up. To answer this question, one would need to know (1) the approximate percentage of refrigerators picked up by dealers, municipalities, and other related businesses that are reconditioned and resold in the local area; (2) how many are sold outside of the utility service area or to another country; and (3) how many are junked. The goal of this additional survey research effort would be to determine the percentage of refrigerators that are ultimately junked through utility turn-in programs, municipal appliance disposal programs, recycling centers, and any other relevant disposal methods.

Information on the frequency with which various refrigerator disposal methods are used could then be used to weight refrigerator age-related data gathered from each of the disposal methods. A strategy could be developed to determine the ages of a sample of refrigerators disposed of through various methods (e.g., utility turn-ins, municipal pick-ups, junkyards, recycling centers). These disposal businesses could track the ages of the refrigerators they collect and junk (through some type of incentive program), or a contractor familiar with refrigerator turn-in programs could be hired to visit these sites and determine the ages of a sample of refrigerators prior to dismantling. Information from all of these businesses would be essential in order to get a representative sample of junked refrigerators. Utility turn-in programs collect information on only a subset of the refrigerators that are eventually junked within a utility service area. As a result, an effective useful life estimate based solely on the ages of these program refrigerators would not necessarily represent of the population of junked refrigerators.

1. California DSM Measurement Advisory Committee (CADMAC), *DSM Measure Life Project: Master Tables of Measure Life Estimates and Final Report*, September 1993.

2. California DSM Measurement Advisory Committee (CADMAC), *California Efficient Refrigerator Programs: Review of Existing Methods and Data Sources*, October 1993.

3. Pacific Gas and Electric, *Refrigerator Turn-in Program -- Executive Summary*, Vol. 1, June 1993.

4. San Diego Gas and Electric, *1993 Home Energy Survey.*

5. Pacific Gas and Electric, *Impact Report: Evaluation of the Refrigerator Incentive Programs*, November 1992.

6. Niagara Mohawk Power Corporation, *Annual Evaluation of BID-4 Refrigerator Roundup™ Program: Final Report*, May 1992.

7. Niagara Mohawk Power Corporation, *Evaluation of the 1992 Refrigerator Roundup™ Program*, 1993.

8. California DSM Measurement Advisory Committee (CADMAC), *DSM Measure Life Project: Master Tables of Measure Life Estimates and Final Report*, September 1993.

SECTION 5: REVIEW OF REBOUND EFFECTS

This section presents a review of the existing assumptions about possible rebound effects of refrigerator incentive programs and the data and methods used to support these assumptions. This task also includes a review of past studies that addresses rebound effects of refrigerator incentive programs, the issues associated with the measurement of rebound effects, and a recommended approach to future measurement.

DEFINITION(S) OF REBOUND EFFECT

The rebound effect is also commonly referred to as the takeback or snapback effect. The California protocols define rebound effect as "a change in energy-using behavior that yields an increased level of service and that occurs as a result of taking an energy efficiency action" (see CADMAC, 1992).[1]

Rebound has been described as an effect that reduces the savings from efficiency measures ". . . as consumers use some of the money they save from energy efficiency measures to purchase increased comfort or convenience by operating energy-consuming equipment more intensely (e.g., increased hours of operation, higher temperature settings, or increased lighting levels)" (see Steven M. Nadel, 1993).[2] Unlike the first description, this description includes consumers who purchase larger units or units with more features because of a DSM program.

In a recent effort to more precisely define the components of the rebound effect, rebound was referred to as:

> ". . . the phenomenon in which the amount of energy savings that results from an energy-efficiency improvement is reduced from the level that would have been achieved at a constant level of energy services, due to the fact that consumers increase their consumption of energy services in response to a DSM-induced reduction in its unit cost. Thus, snapback [rebound] is characterized by an increase in energy consumption relative to a hypothetically lower level that could have been achieved at a constant energy service level, but not necessarily an increase relative to the base-case level of consumption. That is, energy savings are reduced, but are not negative" (see David J. Glyer and Steven D. Braithwait, 1993).[3]

This study characterized rebound as consisting of three categories of effects: (1) direct rebound effects on capacity of energy efficiency measures (EEMs); (2) direct rebound effects on utilization of EEMs; and (3) indirect rebound effects. A general description of each of these categories, as well as its applicability to refrigerator incentive programs, is discussed below.

Direct Rebound Effects on Capacity of EEMs. This category of effect consists of customers who increase the capacity of the equipment they purchase because of the DSM program. For refrigerator incentive programs, this category would include customers who purchased larger refrigerators or refrigerators that had more features than they would have purchased in the absence of a DSM program. The increased energy use associated with the additional size and features represents a direct rebound effect on the capacity of the energy efficiency measure.

Direct Rebound Effects on Utilization of EEMs. This category of effect consists of customers who consciously or subconsciously decide to use a particular piece of equipment they purchase through a DSM program more (i.e., increase their utilization) than the equipment it replaced. For refrigerators, this category of effect can be broken down into the following two subcategories:

> *DSM-Purchased Refrigerator Utilization Effects.* This first subcategory is perhaps the most obvious. It consists of customers who use their refrigerators purchased through a DSM program more than the refrigerators that were replaced. Examples of this effect include customers who open the refrigerator doors more often, leave the refrigerator doors open for longer periods of time, or set the thermostat on a lower temperature setting because the refrigerator is more energy-efficient. The additional energy use associated with these behaviors and actions would be a direct rebound effect due to increased utilization of the DSM-purchased refrigerator.
>
> *Second-Refrigerator Utilization Effects.* The second subcategory of the utilization effect is primarily concerned with the impact of refrigerator rebate programs on the use of second refrigerators. Examples of this effect would include situations where (1) customers decide to keep their old refrigerator because of some type of program influence; (2) customers purchase a refrigerator through the incentive program solely for use as a second refrigerator and they would not have purchased this second refrigerator in the absence of a program; and (3) customers purchase a refrigerator through an incentive program as a replacement for a second refrigerator and decide to keep the new refrigerator plugged in more often because it is more energy-efficient. These situations involve increases to the total cubic feet of refrigeration utilized within a household. The additional energy use associated with these behaviors and actions would be a direct rebound effect due to increased second-refrigerator utilization.

Indirect rebound effects. Indirect rebound effects are much more difficult to measure. These effects consist of situations where customers increase their utilization of <u>other</u> electric appliances and equipment because the installation of the energy-efficient refrigerator reduces their overall electric bill. This effect is generally thought to be ". . .small, relative to the direct effects; for a residential consumer, for example, even substantial savings in spending on energy amount to only a small fraction of income" (see David J. Glyer and Steven D. Braithwait, 1993).[4]

CURRENT REBOUND EFFECT ESTIMATES

As found in Section 1 of this study, none of the major investor-owned electric utilities (i.e., Pacific Gas and Electric Company (PG&E), San Diego Gas and Electric Company (SDG&E), or Southern California Edison (SCE)) include estimates of rebound effects in their refrigerator program impact estimation methodology (see HBRS, Inc., 1993).[5] This is at least in part due to the fact that only a few studies of refrigerator incentive programs have included a formal methodology to address possible rebound effects. A recently completed comprehensive literature search for a review of past rebound effect studies could only identify two that formally addressed the rebound effect for refrigerators (see Steven M. Nadel, 1993).[6] These studies were completed by PG&E (see HBRS, Inc., 1992)[7] and Wisconsin Power and Light (see WP&L, 1992).[8]

PAST REBOUND EFFECT STUDIES

The statistics outlined in this section were collected as part of PG&E's 1992 refrigerator incentive program evaluation. The evaluation completed by WP&L included a number of residential appliances and, as a result, provides only limited information about refrigerator program rebound effects. Both of these evaluations will be discussed in the context of the three categories of effects outlined in the above definitions section.

Direct Rebound Effects on Capacity of EEMs. This category of effect includes the additional energy use associated with customers who increase the capacity or features of the refrigerators they purchase because of a DSM program. Both WP&L's and PG&E's refrigerator program evaluations showed very little evidence of any direct rebound effect on refrigerator capacity. The WP&L study showed that only 5 percent of customers who received rebates reported they purchased a larger refrigerator than they had initially planned to purchase. Specific statistics from the 1992 PG&E evaluation that support the conclusion of a small or nonexistent rebound effect on capacity include the following:

- The evaluation revealed that the average self-reported size of refrigerators purchased by participants (20.0 cubic feet) and nonparticipants (20.9 cubic feet) did not differ significantly (Table 5.1). Participants and nonparticipants were also asked about the attributes of their old refrigerator in order to make comparisons to the new refrigerators. Nonparticipants reported larger increases in the size of their new refrigerator as compared to their old refrigerator than did program participants (Table 5.1).

Table 5.1: Average Size of New and Old Refrigerator

	Participant	Nonparticipant
Average size of new refrigerator (cubic feet)	20.0 (307)	20.9 (172)
Average size of old refrigerator (cubic feet)	18.6 (242)	17.8 (132)
Difference (cubic feet)	1.4	1.9

( ) Number in parentheses the number of respondents.

- Participants in PG&E's refrigerator incentive program purchased refrigerators with fewer features than program nonparticipants (Table 5.2). Nonparticipants (36 percent) were more likely than participants (23 percent) to purchase a refrigerator with an ice maker through the door. Additionally, nonparticipants (52 percent) were more likely than participants (29 percent) to purchase a refrigerator with an ice maker inside the freezer compartment.

Table 5.2: Proportion of New Refrigerators with Key Features

	Participant	Nonparticipant
Frost-free	97%	95%
Humidity switch	58	59
Ice maker through the door	23	36
Ice maker inside the freezer	29	52
Cold water through door	20	29
Other features	3 (396)	4 (197)

( ) Number in parenthesis is the number of respondents.

- Sales data from a sample of refrigerator dealers were also collected as part of PG&E's 1992 evaluation. The sales data revealed that in 1991 the average adjusted volume[7] for top-mount refrigerators sold in PG&E's service territory (21.05 cubic feet) was very similar to the average adjusted volume for top-mount refrigerators sold in the rest of California (20.98 cubic feet). The difference in energy consumption between these two size categories was only 3 kWh per year.[8] The average adjusted volume of a top-mount refrigerator sold nationally in 1991 was 20.64 cubic feet.

  The sales data also revealed that in 1991, the average adjusted volume for side-by-side refrigerators sold in PG&E's service territory (28.65 cubic feet) was very similar to the average adjusted volume for a side-by-side refrigerator sold in the rest of California (28.21 cubic feet). The difference in energy consumption between these two size categories in only 19 kWh per year.[9] The average adjusted volume of a side-by-side refrigerator sold nationally in 1991 was 27.55 cubic feet. This was over 1 cubic foot less than a side-by-side sold in PG&E's service area.

Direct Rebound Effects on Utilization of EEMs. As previously described, this category of effect can be broken down into two subcategories. These subcategories are (1) DSM-purchased refrigerator utilization effects and (2) second refrigerator utilization effects. Neither the PG&E study nor the WP&L study addressed DSM-purchased refrigerator utilization effects. These effects consist of situations where customers open refrigerator doors more often, leave refrigerator doors open for longer periods of time, or set the thermostat on a lower temperature setting because the refrigerator is more energy-efficient.

A limited amount of information was collected in the PG&E study that addressed second-refrigerator utilization effects. These types of effects involve increases to the total cubic feet of refrigeration utilized within a household.

PG&E's refrigerator program evaluation found no evidence of any direct rebound effect on second-refrigerator utilization. In fact, the PG&E study found that program nonparticipants were more likely to keep their old refrigerator than were program participants (Table 5.3).

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[7]Adjusted volume for a refrigerator-freezer was calculated by multiplying cubic-foot freezer volume by 1.63 and adding this amount to cubic-foot fresh-food volume.

[8]This calculation was made by using the average energy factor (9.38) for a top-mount refrigerator sold in PG&E's service area in 1991.

[9]This calculation was made by using the average energy factor (8.44) for a side-by-side refrigerator sold in PG&E's service territory during 1991.

Table 5.3: Disposition of Old Refrigerator

	Participant	Nonparticipant
What did you do with your old refrigerator?		
Kept it (second-refrigerator effect)	18%	26%
Gave it away	32	32
Sold it	7	10
Junked it myself	7	9
Paid to have it hauled away	11	10
Left it . . . when moved	7	6
Traded it in	5	4
Other	13	3
	(334)	(165)

( ) Number in parenthesis is number of respondents

The PG&E study did not collect data on the remaining two second-refrigerator effects: customers who purchase a refrigerator through a refrigerator incentive program for use as a second refrigerator who would not have done so in the absence of a program and customers who purchase a refrigerator through an incentive program as a replacement for an existing second refrigerator if they decided to keep the new-second refrigerator plugged in more often.

Indirect Rebound Effects. As discussed above, indirect rebound effects are much more difficult to measure. Neither the PG&E nor WP&L study addressed indirect rebound effects.

REBOUND EFFECT ISSUES

There are a number of important issues associated with measuring the rebound effects of refrigerator incentive programs. Any measurement technique will need to take the following issues into account.

Participants in refrigerator programs may have a pre-disposition to purchase refrigerators with fewer features. Features such as through-the-door ice, through-the-door water, and automatic ice-makers within the freezer compartment may have less appeal to program participants regardless of whether they participate in a DSM program. Participants may also have an underlying predisposition to purchase refrigerators that are smaller. As a result, nonparticipant purchases may not be a good indicator of what participants would have done in the absence of a DSM program. For example, if a comparison of participants to nonparticipants revealed that 30 percent of both groups purchased refrigerators with automatic ice makers, this would be one indicator of a nonexistent rebound effect on capacity. However, what if only 10 percent of program participants would have purchased this feature in the absence of the program? A simple comparison of participant and nonparticipant purchases would not provide this insight.

The entire market for refrigerators may be impacted by a DSM program. Both participant and nonparticipant purchases could be impacted by refrigerator incentive programs. As a result, the size and feature distributions of refrigerators purchased by nonparticipants may also be influenced by the DSM program. The DSM program could have a sufficient impact on the market to change the equipment available to all consumers. Under these circumstances, nonparticipant purchases would not be a good indicator of participant purchases in the absence of a DSM program.

Refrigerator features may have a dramatic impact on annual energy consumption. The energy use associated with additional features like automatic ice makers is not completely included in Department of Energy (DOE) test procedures. The total energy use from automatic ice makers consists of the following four components (see John Proctor, 1993):[9]

- the energy required to freeze water
- the energy expended by the heater that warms the ice mold so ice can be removed
- the energy expended by the motor that pushes the ice out of the mold
- the energy required by the compressor to remove this extra heat from the freezer

It has been suggested that automatic ice-makers add as much as 10 to 15 percent to the annual energy consumption of a refrigerator (see Alan K. Meier, 1993).[10] Any attempt to measure the rebound effect of refrigerator incentive programs must take the issue of energy use due to additional features into consideration.

A comparison of the DOE test results for refrigerators with and without through-the-door features (i.e., a comparison of the individual DOE test results for models with through-the-door features to the same models without through-the-door features) revealed that through-the-door features uniformly add 10 percent to a refrigerator's annual energy consumption. These comparisons may understate the actual increase in energy-use because through-the-door features are not utilized during the DOE test procedures (i.e., no water or ice is used). The DOE estimates reflect only the thermal loss that results from having through-the-door features. These thermal losses result from the fact that through-the-door features require creating openings in the refrigerator that can not be insulated. Since the through-the-door features are not utilized during DOE tests, the total increase in annual energy use associated with these features may even exceed 10 percent (see Alan K. Meier, 1993).[11] Any attempt to measure the rebound effect of refrigerator incentive programs must take this issue into consideration.

The annual energy consumption attributable to additional refrigerator door openings, more lengthy openings, and lower thermostat setting is uncertain. While no formal field tests have been made to measure the impact of these features and actions, one study completed in a laboratory setting found that tests of 100 door openings per 24 hours will increase energy use about 25 percent for a typical top-mount refrigerator (see M. Alissi, et al., ASHRAE Transactions, Vol. 94).[12] Although only one study has been completed, the results appear to warrant additional research.

SUMMARY AND RECOMMENDED APPROACH

Formal studies geared toward estimating of the rebound effects of refrigerator incentive programs are currently lacking. A number of current data collection mechanisms could potentially be expanded to include the collection of information that would provide additional insight into the possible rebound effects of these programs. However, no one data collection method will provide a complete picture of potential rebound effects. Instead, a combination of approaches appears to be both relevant and feasible.

The following discussion outlines an approach for measuring the potential rebound effects of refrigerator incentive programs. The discussion addresses each of the three categories of effects.

Direct Rebound Effect on Capacity of EEMs. Rebound effects of this nature can and have been measured through customer surveys. This is accomplished either by asking program participants and nonparticipants about the size and features of their old and new refrigerators or by asking them to record the brand name and model number for both refrigerators. This brand name and model number information enables the researcher to look up the energy use and features of a refrigerator in a efficiency guide, such as the Association of Home Appliance Manufacturer's (AHAM) Certified Directory of Refrigerators and Freezers. A comparison of old and new refrigerators for the two groups will provide insight into the magnitude of any rebound effect on capacity. As mentioned previously (see "Rebound Effect Issues"), a comparison of participants and nonparticipants may not be completely appropriate if participants have a predisposition to purchase refrigerators with fewer features or if the entire refrigeration market has been impacted by the DSM program.

Although a comparison of participants and nonparticipants may still be useful, a comparison of sales data within a utility service area to sales data in a comparison area that is not influenced by DSM programs may also be necessary. Brand name and model number sales data would have to be collected so that the basic features of models sold in each area could be determined and compared. Any such efforts would have to be supplemented with additional field metering data to capture the annual energy use associated with automatic ice makers and through-the-door features because current DOE test procedures capture only a portion of this energy use. The combination of survey and/or sales data and additional metering studies would potentially allow program evaluators to modify program impacts to reflect rebound effects.

Direct Rebound Effect on Utilization of EEMs. This effect consists of the direct rebound effect on utilization of DSM-purchased refrigerators and the direct rebound effect on utilization of second refrigerators. Each of these sub-categories of direct rebound effects on utilization of EEMs will be discussed below.

Direct rebound effect on utilization of DSM-purchased refrigerators. This rebound effect includes the additional energy use associated with such actions as opening the refrigerator doors more often, leaving the doors open for longer periods of time, and turning the thermostat to a lower setting because the DSM-purchased refrigerator is more energy-efficient. Relative to other potential rebound effect categories, this category of effect appears to be both difficult to formally measure and unlikely to be large. Despite these concerns, it may be cost-effective to include some measurement of this effect as part of refrigerator sub-metering efforts. Conditional demand analysis also has the potential to provide insight into this effect.

Direct rebound effect on utilization of second refrigerators. This rebound effect can and has been measured through the use of customer surveys. This typically involves a relatively detailed set of questions that attempt to determine both the number and types of refrigerators in participating and nonparticipating customers' residences prior to purchasing the new refrigerator and after the actual purchase. The primary issue to be addressed would be whether the program is inducing participants to keep their old refrigerator and use it as a second refrigerator at a higher rate than nonparticipants. While survey data will provide information on the rate at which second refrigerators are used, although it will not necessarily provide an accurate picture of the increased energy use associated with this decision. Ultimately, the goal of any study of second refrigerator utilization effects is to determine the amount of increased energy use associated with second refrigerators that would not have been used in the absence of a DSM program. Conditional demand analysis and/or sub-metered data for a sample of customers who kept their second refrigerators could potentially help to determine the total energy use associated with these units. This, combined with survey data that measures the overall magnitude of this problem, could be used to modify program impacts.

Indirect Rebound Effects. Indirect rebound effects of refrigerator incentive programs would be very difficult to determine and any such effect is likely to be minimal relative to the potential direct rebound effects.

1. Steven M. Nadel, "The Takeback Effect: Fact or Fiction?" *Proceedings of 1993 Energy Program Evaluation Conference*, CONF-930842, NEPEC, Chicago, IL, August 1993, p.558.

2. Steven M. Nadel, "The Takeback Effect: Fact or Fiction?" *Proceedings of 1993 Energy Program Evaluation Conference*, CONF-930842, NEPEC, Chicago, IL, August 1993, p. 558.

3. David J. Glyer and Steven D. Braithwait, "Persistence and Snapback in DSM Program Planning and Evaluation," *Proceedings of 1993 International Energy Program Evaluation Conference*, CONF-930842, NEPEC, Chicago, IL, August 1993, p. 502.

4. David J. Glyer and Steven D. Braithwait, "Persistence and Snapback in DSM Program Planning and Evaluation," *Proceedings of 1993 International Energy Evaluation Conference*, CONF-930842. NEPEC, Chicago, IL, August 1993.

5. HBRS, Inc., *"California Efficient Refrigerator Programs: Review of Existing Methods and Data Sources,"* Prepared for the subcommittee on Residential High Efficiency Refrigerator Studies--California DSM Measurement Advisory Committee (CADMAC), October 1993.

6. Steven M. Nadel, "The Takeback Effect: Fact or Fiction?" *Proceedings of 1993 Energy Program Evaluation Conference*, CONF-930842, NEPEC, Chicago, IL, August 1993.

7. HBRS, Inc., *"Impact Report: Evaluation of the Refrigerator Incentive Programs,"* Prepared for Pacific Gas and Electric Company, November 1992.

8. Wisconsin Power and Light, *"1989 BuySmart Evaluation: Process and Market Issues,"* June 1992.

9. John Proctor, "What's Wrong with Refrigerator Energy Ratings?" *Home Energy Magazine*, January/February 1993.

10. Alan K. Meier, Lawrence Berkeley Laboratory, Personal communication, October 1993.

11. Alan K. Meier, "Through-the-Door Energy Use," *Home Energy Magazine*, January/February 1993.

12. M. Alissi, et al., *"Effects of ambient temperature, ambient humidity, and door openings on energy consumption of a household refrigerator-freezer,"* ASHRAE Transactions, Vol. 94, pt. 2, pp. 1713-1735.

SECTION 6: STATEWIDE REFRIGERATOR PROGRAM EVALUATION MEASUREMENT PLAN

This section presents the research plan that HBRS recommends the California electric utilities undertake to examine various issues surrounding the estimation of the impacts of their refrigerator programs.

PROPOSED STUDIES BY IMPACT PARAMETER

The following discussion outlines proposed studies to examine the estimation of key impacts of DSM refrigerator programs. The discussion is broken out by impact parameter.

Energy. PG&E and SCE should complete their studies comparing metered consumption with results of estimates based on DOE testing procedures. If the preliminary findings that the test results provide reliable estimates of "in-field" electricity use are corroborated by SCE's efficient refrigerator metering study, then no further studies will be planned until such time as changes in refrigerator design (e.g., applications of variable speed compressors) are judged to warrant review of this issue again.

Peak Demand Load. PG&E and SCE should calculate the hourly load shapes for efficient refrigerators from their metering samples of recent program participants. These should be compared tot he results of their general end use load studies. If comparisons confirm the finding of this study that the relative hourly loads (i.e., measured load divided by average load) for key costing periods vary significantly by efficiency level, then the new load curves should be used for estimating the critical period load impacts. The utilities should investigate further whether conditioning the average load estimates on other refrigerator and customer characteristics accounts for the differences. This would involve regression analyses where the recorded loads are regressed against variables representing these characteristics.

Effects of Useful Life. Commission two statewide studies:

(1) **A Study of Effective Useful Life of Refrigerators as Recommended in Draft Chapter 4 (Review of Estimates of Useful Life).** This study would estimate the effective useful life of refrigerators as defined in the California Collaborative. The study would track the disposition of old refrigerators by surveying households, refrigerator dealers, recycling contractors, disposal centers, and other entities that process used refrigerators. The surveys would record the ages of replaced refrigerators and the percentage of them that were re-used versus those that were scrapped. This information would be used to estimate the disposition pattern for old refrigerators and the median age of the ones that are scrapped.

Survey Research to Collect Data to Estimate Effective Useful Life of Disposed of Refrigerators. Expand current survey data collection techniques implemented as part of refrigerator program evaluations to more clearly and concisely track replaced refrigerators. This will involve contacting a random sample of residential customers in order to identify those who disposed of a refrigerator in the last year.

Determining who the refrigerator was given to is a key variable of interest. Those most likely to have picked up the replaced refrigerators include refrigerator dealers, utility turn-in programs, and municipal appliance disposal programs. Replaced refrigerators could also have been given to or sold to another individual, moved to the basement or garage, or moved to another residence, such as a cottage. Additional survey follow-up is needed to find out what the second parties did with the refrigerator. Presumably, most utility turn-in programs result in the refrigerators being disposed of in an environmentally safe manner. However, it is not clear what dealers, municipalities, and other related businesses do with the refrigerators they pick up. To answer this question, one would need to know (1) the approximate percentage of refrigerators picked up by dealers, municipalities, and other related businesses that are reconditioned and resold in the local area; (2) how many are sold outside of the utility service area or to another country; and (3) how many are junked.

The goal of this additional survey research effort is to determine the percentage of refrigerators that are ultimately junked through utility turn-in programs, municipal appliance disposal programs, recycling centers, and any other relevant disposal methods.

Information on the frequency with which various refrigerator disposal methods are used will then be used to weight refrigerator age-related data gathered from each of the disposal methods. A strategy will be developed to determine the ages of a sample of refrigerators disposed of through various methods (e.g., utility turn-ins, municipal pick-ups, junkyards, recycling centers). These disposal businesses can track the ages of the refrigerators they collect and junk (through some type of incentive program). Information from all of these businesses is essential in order to get a representative sample of junked refrigerators. Utility turn-in programs collect information on only a subset of the refrigerators that are eventually junked within a utility service area. As a result, an effective useful life estimate based solely on the ages of these program refrigerators would not necessarily represent of the population of junked refrigerators.

Study Engineering Useful Life Versus Effective Useful Life of Disposed of Refrigerators and Develop Adjustment Factors to Adjust Engineering Useful Life of New Refrigerators. Research and develop an adjustment factor to apply to the engineering useful life of new refrigerators. This factor will be based on the ratio of effective useful life to engineering life of currently disposed of refrigerators. The description of the information proposed to be collected above will be used to address the useful life of currently disposed of refrigerators and is not representative of the effective useful life of new refrigerators. New refrigerators vary significantly from older refrigerators in construction and feature. The impacts of these new features on effective useful life of refrigerators is unknown. It is inappropriate to use effective useful life estimates that have been based on older refrigerators. An adjustment factor will be developed to apply to the engineering useful life of new refrigerators based on the ratio of effective useful life to engineering life of currently disposed of refrigerators.

2) **A Study of the Effect of Refrigerator Turn-in Programs on Reducing Effective Useful Life of Old Refrigerators.** With the start of refrigerator turn-in programs, the effective useful life of refrigerators will be affected by this additional factor. Assess the

impact of this effect through a state-wide survey of randomly selected residential customers that participated in refrigerator turn-in programs and a group of nonparticipants. The survey will examine changes in participants use of refrigerators due to the program and changes in nonparticipants use of refrigerators due to other factors besides the program. Results will be compared and adjusted.

Net-to-gross. Commission two studies to investigate components of net-to-gross:

1) **A Study of Free-Ridership and Spillover Effects as Recommended in Draft Chapter 3 (Assessment of Refrigerator Sales and Shipment Data).**

Assess free-ridership and spillover effects with the use of a combination of sources of sales and/or shipment data. The calculations are a formidable task. However, these calculations can be done at both a utility service territory and state level. The calculation of these effects will involve many detailed tasks to collect information from various sources of sales and/or shipment data that is needed to compute net-to-gross ratios and to estimate other program effects, such as spillover.

Retail-level sales data at the store level will provide both the geographical precision and efficiency data necessary to estimate the distribution of efficiencies by utility service area and for the entire state of California. A random-digit-dial approach will also be used to provide this information with the necessary geographical precision. This random-digit-dial approach will be used as a method of checking the representativeness of the sales data collected through a retail approach. Finally, data provided by major retailers for comparison areas outside of California as well as AHAM national shipment weighted data will provide the necessary "control" areas. This triangulation (i.e., retail-level data, random-digit-dial data, AHAM data) in combination with other information currently collected by utilities (e.g., appliance saturation surveys) and the California Energy Commission (e.g., county-level shipment data purchased from AHAM) will allow for net-to-gross ratio calculations and estimates of spillover at both a utility service area and state level.

This approach is not without its limitations. The most significant limitation is the fact that cooperation rates among major national and regional retailers cannot be guaranteed. However, the combined influence of the California Energy Commission and the major investor-owned utilities should have a considerable impact on these retailers.

2) **A Study of Rebound Effect as Recommended in Draft Chapter 5 (Review of Rebound Effects).**

Conduct formal studies geared toward estimating of the rebound effects of refrigerator incentive programs. Currently this information is not available. A combination of data collection methods will be employed that will be both relevant and feasible.

The following discussion outlines the approach for measuring the potential rebound effects of refrigerator incentive programs. The discussion addresses each of two major categories of effects.

Direct Rebound Effect on Capacity of Energy Efficiency Measures (EEMs). Conduct customers surveys to measure rebound effects. This will be accomplished by asking program participants and nonparticipants about the size and features of their old and new refrigerators and by asking them to report the brand name and model number for both refrigerators, if available. This brand name and model number information enables the researcher to look up the energy use and features of a refrigerator in a efficiency guide, such as the Association of Home Appliance Manufacturer's (AHAM) Certified Directory of Refrigerators and Freezers. A comparison of old and new refrigerators for the two groups will provide insight into the magnitude of any rebound effect on capacity. However, a comparison of participants and nonparticipants may not be completely appropriate if participants have a predisposition to purchase refrigerators with fewer features or if the entire refrigeration market has been impacted by the DSM program.

A comparison of participants and nonparticipants is useful, but as a check, a comparison of sales data within a utility service area to sales data in a comparison area that is not influenced by DSM programs is also necessary. Brand name and model number sales data will have to be collected so that the basic features of models sold in each area could be determined and compared. Any such efforts would have to be supplemented with additional field metering data to capture the annual energy use associated with automatic ice makers and through-the-door features because current DOE test procedures capture only a portion of this energy use. The combination of survey and/or sales data and additional metering studies would potentially allow program evaluators to modify program impacts to reflect rebound effects. If necessary, sub-metering could be substituted with a conditional demand analysis.

Both approaches (i.e., participant and nonparticipant surveys versus comparison of sales data) will be used to estimate this rebound effect in an effort to "bound" the magnitude of the estimate.

Direct Rebound Effect on Utilization of EEMs. This effect consists of the direct rebound effect on utilization of second refrigerators. This component of direct rebound effects on utilization of EEMs is discussed below.

Direct rebound effect on utilization of second refrigerators. This rebound effect can and has been measured through the use of customer surveys. This typically involves a relatively detailed set of questions that attempt to determine both the number and types of refrigerators in participating and nonparticipating customers' residences prior to purchasing the new refrigerator and after the actual purchase. The primary issue to be addressed would be whether the program is inducing participants to keep their old refrigerator and use it as a second refrigerator at a higher rate than nonparticipants. While survey data will provide information on the rate at which second refrigerators are used, although it will not necessarily provide an accurate picture of the increased energy use associated with this decision. Ultimately, the goal of any study of second refrigerator utilization effects is to determine the amount of increased energy use associated with second refrigerators that would not have been used in the absence of a DSM program. Submetered data for a sample of customers who kept their second refrigerators will be used to determine the total energy use associated with these units. This, combined with survey data that measures the overall magnitude of this problem, could be used to modify program impacts.