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Pacific Gas & Electric Company Refrigerator – Part Two

Costing Period Study

Prepared for:
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Customer Efficiency Program
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Residential Refrigerator Metering Analysis - Part Two PG&E Costing Period Study

I. EXECUTIVE SUMMARY

In the residential sector, energy efficient refrigerators offer one of the most effective opportunities for reducing electricity demand and delaying the construction of new power plants and/or transmission and distribution facilities. In 1990, 1991, and 1992, Pacific Gas and Electric Company (PG&E) offered rebates for refrigerators that were more efficient than the (1990) Federal standards, as reported on the label. The amount of the rebate increased with efficiency. Refrigerators were grouped as 10-14.9% better than the Federal standards, 15-19.9% better, etc. The labeled energy consumption of refrigerators is based on a specified laboratory test procedure (ANSI/AHAM HRF-1-1988), also known as the DOE test.

In the largest in-home refrigerator study to date, two hundred and fifty-six new refrigerators were metered in three geographic areas within PG&E's service territory for one year (August 1992 - August 1993). In part one, (Annual Energy Consumption Comparison) the energy consumption of two groups of new refrigerators (10 to 14.9% and 30 to 34.9% better than the 1990 Federal standard) was compared to their labeled consumption. In part two of this study the energy consumption and load shape for each of PG&E's costing periods were developed for two groups of refrigerators - Group E and Group T[1]. With this information energy savings and peak reductions from high efficiency replacements were evaluated. The Costing Period Study determined peak reductions for: 1) the replacement of a "typical" existing refrigerator, and 2) for the change from a theoretical refrigerator that just meets the current standards to a higher efficiency unit. The more efficient metered refrigerators were compared against PG&E Appliance Metering Project (AMP) refrigerator data and against the federal standard.

Results

This study produced factors to estimate the actual annual energy consumption, energy consumption by cost period, and peak watt draw by cost period for both new and existing refrigerators. The calculations and mathematical factors are contained in the body of the report. Using these factors energy consumption and peak load for three

[1] Group E consists of 120 refrigerators that, on average, are slightly more efficient than the 1993 Federal standards. The annual consumption of these refrigerators is 599 kWh in PG&E's service territory. Group T consists of 40 refrigerators (from PG&E's AMP) that, on average, are 12 years old, and consume 1301 kWh in PG&E's service territory.

refrigerator prototypes were calculated. The three prototypes are: a "standard" refrigerator that just meets the 1993 Federal standards, a "rebated" refrigerator that has a labeled consumption 80% of the standard, and a "typical" refrigerator that exists in PG&E's residential service territory. The results are shown in Table 1.

Table 1. Annual Electrical Consumption and Coincident Peak for New and Existing Refrigerators

	Annual Consumption (kWh)	Labeled Annual Consumption (kWh)	Summer Coincident Peak (Watts) 4pm
1993 Standard[a]	617	716	110
Rebated[b]	493	573	88
Typical[c]	1255		201

a. Based on a refrigerator with a labeled consumption that just meets the standards. This theoretical unit is a 19.3 cubic foot, top freezer, automatic defrost refrigerator with an adjusted volume of 22.79 cubic feet in a home with 2.54 occupants.
b. Based on a refrigerator with a labeled consumption 80% of the standard, with volume and occupancy the same as the Standard refrigerator.
c. Based on an average 12 year old refrigerator with volume and occupancy the same as the Standard refrigerator.

As shown in Table 2 there are significant energy savings and peak reductions available when higher efficiency "rebated" refrigerators replace lower efficiency "typical" or "standard" units. In PG&E's service territory, 763 kWh is saved by replacing a "typical" existing refrigerator with a new high efficiency "rebated" refrigerator. This replacement will also reduce the summer coincident peak by 113 watts. In addition, the "rebated" refrigerator will use 123 kWh less than a theoretical refrigerator that just meets the standard. The associated peak reduction is 22 watts.

Table 2. Energy Savings and Coincident Peak Reduction for New and Existing Refrigerators

	Annual Energy Savings (kWh)	Labeled Change in Consumption (kWh)	Coincident Peak Reduction (Watts) 4pm
Rebated vs. Standard	123	143	22
Rebated vs. Typical	763		113

Conclusions

Based on the PG&E refrigerator metering study reasonable estimations of energy savings and peak reduction impacts can be made for:

1) the selection of a more efficient new refrigerator over a less efficient new refrigerator of the same size and style.
2) the replacement of an existing refrigerator with a new refrigerator of the same size and style.

The labeled energy consumption of refrigerators is based on a 90°F room temperature test. This high temperature produces higher energy consumption than actually occurs in the homes in PG&E's service territory. The metering results on rebated customers homes show that the overprediction of consumption (and savings) is 13.8%.

In the selection of new refrigerators the net energy savings and peak reduction will depend on the baseline refrigerator and net-to-gross effects. For an existing refrigerator, the energy consumption and peak use calculated from the equations and factors in this report can be used as a conservative baseline.

Recommendations

The applicability of this data is dependent on two relationships:

1) the relationship between the daily consumption and the load by hour - the load shape ratios,
2) the relationship between the yearly consumption and the labeled consumption.

It is recommended that these two relationships now be tested on a smaller sample of new refrigerators of a variety of sizes and types. Thereafter these relationships should be checked as standards change, or every other year to capture design changes. With higher standards, the trend toward higher cabinet efficiency is likely to continue. As a result, occupant effects will become a larger portion of the annual consumption. This shift could effect both of these relationships.

II. INTRODUCTION

In the residential sector, energy efficient refrigerators offer one of the most effective opportunities for reducing electricity demand and delaying the construction of new power plants and/or transmission and distribution facilities. In 1990, 1991, and 1992, Pacific Gas and Electric Company (PG&E) offered rebates for refrigerators that were more efficient than the (1990) Federal standards, as reported on the label. The amount of the rebate increased with efficiency. Refrigerators were grouped as 10-14.9% better than the Federal standards, 15-19.9% better, etc. The labeled energy consumption of refrigerators is based on a specified laboratory test procedure (ANSI/AHAM HRF-1-1988), also known as the DOE test.

Three questions have been posed:

1) How closely does the labeled consumption represent energy consumption under actual use?
2) How is the annual energy consumption broken down by PG&E costing period?
3) What is the load shape of these new refrigerators in different costing periods?

These questions become fundamental in utility Demand Side Management programs, such as the PG&E refrigerator rebate program. DSM programs invest in end use energy efficiency to offset supply-side investments. For an accurate assessment of investment alternatives the costs and energy savings of DSM measures must be known. When customers choose one level of refrigerator efficiency over another, there is an impact on energy use and peak demand. The actual amount of this impact was the subject of this two part study.

In part one, (Annual Energy Consumption Comparison) the energy consumption of two groups of new refrigerators was compared to their labeled consumption. In the largest in-home refrigerator study to date, two hundred fifty six new refrigerators were metered in three geographic areas (Coastal - Hayward, Inland - Livermore, and Central Valley - Fresno) for one year. That study concluded that refrigerator energy consumption in PG&E's service territory is less than the labeled consumption.

In part two, (PG&E Costing Period Study) the energy consumption and load shape for each costing period were developed for two groups of refrigerators. With this information energy savings and peak reductions from high efficiency replacements were evaluated. The Costing Period Study determined peak reductions for: 1) the replacement of a "typical" existing refrigerator, and 2) for the change from a theoretical refrigerator that just meets the current standards to a higher efficiency unit. The more efficient metered refrigerators were compared against PG&E Appliance Metering Project (AMP) refrigerator data and against the federal standard.

This report covers the second part of the metering study which had the following research objectives:

1) For each of PG&E's five costing periods, estimate the kW reduction associated with high efficiency residential refrigerators and develop adjustment factors to estimate future kW reductions. The PG&E costing periods are:
   - Summer on-Peak: May 1 to October 31, 12 noon - 6 pm, weekdays
   - Summer Partial Peak: May 1 to October 31, 8:30 am-12 noon and 6:00 pm-9:30 pm, weekdays
   - Summer Off Peak: May 1 to October 31, Other
   - Winter Partial Peak: November 1 to April 30, 8:30 am - 9:30 pm
   - Winter Off Peak: November 1 to April 30, Other
2) Estimate the percentage of annual kWh consumption in each of the five costing periods for high efficiency refrigerators metered in the 1992-1993 metering project, a theoretical "standard" refrigerator of the same size and type as those metered in the 1992-1993 project, and a "typical" refrigerator represented in the 1992 AMP data.
3) Produce graphs of the load for high efficiency, "standard," and "typical" refrigerators on a system summer peak day, an average summer day, and an average winter day.

III. METHODOLOGY

The PG&E Costing Period Study compared the annual and hourly electrical consumption of high efficiency refrigerators to "standard" and "typical" refrigerators. The bases of this comparison were metered data from new refrigerators metered in 1992/1993 and from a variety of existing refrigerators drawn from the Pacific Gas and Electric Company Appliance Metering Project.

Sample Selection

The high efficiency sample (Group E) was confined to 17 through 21 ft^3 units with top freezer and automatic defrost. Group E reflects the most common refrigerator size and style purchased under the 1992 rebate program. They also represent refrigerators of the highest efficiency generally sold in 1992. Three geographical areas were chosen: Coastal (clustered near Hayward), Inland (clustered near Livermore), and Central Valley (clustered near Fresno). Group E refrigerators were randomly selected from a list of rebated customers that met the sample selection criteria. The list of rebated refrigerators was prepared by the Electric and Gas Industries Association (EGIA), which processes the rebates for PG&E. This group of refrigerators was selected for the second part of the study because it most closely approximated refrigerators that are now on the market.

The existing refrigerator sample (Group T) was drawn from 1992 AMP study, which was chosen to represent a cross section of PG&E's residential population. AMP refrigerators that had at least three months of summer data and three months of winter data were included in the sample. Based on recorded make and model information the total volume of each refrigerator was checked against recorded total volume. If a significant discrepancy existed on volume or on type of refrigerator, that unit was dropped from the analysis. No side by side units were used in Group T.

Some significant characteristics of both groups of customers are given in Table 3.

Table 3. Characteristics of Sample Groups

	Refrigerator Age	Total Volume	Household Occupants	Central AC
Group E 120 Rebated Customers	1 year	19.0 cu. ft.	2.54	51%
Group T 40 Metered Customers	11.9 years	19.7 cu. ft.	3.1	53%
PG&E Residential Population			3.03 [1]	49% [2]

1. Based on weighted 1990 RASS data for single family residences and town homes. (PG&E, 1994)
2. Based on 1990 RASS data. (XENERGY, 1992)

Data Acquisition

An hourly recording meter (a 120-volt version of PG&E's residential time of use meter) was installed on each Group E refrigerator to measure its energy consumption for up to a full year. At the time of meter installation, a PG&E technician briefly interviewed the occupant(s), and recorded information on factors that might influence refrigerator energy consumption, including number of people in household, use of an automatic ice maker, and anti-sweat heater switch on or off. (See Appendix F for a list of variables) Group T refrigerators were monitored with a variety of submetering devices utilized in the AMP program.

All the data collected by the technicians (occupancy, presence of ice maker, etc.) were checked carefully to eliminate errors. Missing data, inconsistencies in data (i.e. ice maker on but none installed), or changes in data from visit to visit were investigated and clarified either by phone or in person at the next visit. Hourly data from each metered refrigerator were summed to daily total kWh, annualized (multiplied by 365) and matched with the average daily temperatures from the closest weather station. The Fresno airport weather station was used for the Central Valley group, Livermore for the Inland group, and Freemont for the Coastal group.

Data Analysis

A number of alternative analysis approaches were attempted for reducing the influence of usage level factors (such as occupancy) on load shape estimates. One approach involved modeling the ratio of each hour's usage to average load for that refrigerator over the year. This approach "nets out" the impact of usage level from seasonal load patterns and load shapes. However, the denominator of the ratio requires an unbiased estimate of a given refrigerator's annual usage. Unfortunately, the data sets had numerous missing values with potentially biasing patterns (both geographic and seasonal differences were apparent in the attrition), so this method was deemed inappropriate.

An inspection of load shapes at varying usage levels found that the hourly pattern in a given day is relatively unaffected by the daily usage. This observation led to the use of a two step approach for estimating load shapes by costing period. The daily usage could be estimated by a regression model involving temperature and costing period variables. The usage by hour could then be estimated from the daily usage using a ratio approach. The hourly ratios could be estimated by costing period if there was a costing period effect. This approach exploits the consistency of the hourly load shapes.

The two step approach relies upon the assumption that hourly load ratios are independent of temperature effects and usage levels (and factors influencing usage levels such as occupancy) at least within costing periods. This assumption was tested in several ways. Regression models of load in a given hour as a function of daily average load were estimated for different costing periods with and without the inclusion of temperature, occupancy, icemaker presence, and refrigerator volume variables. The average daily load variable dominated the model. Only in the winter was there a temperature effect of any importance. All other household and refrigerator variables produced coefficients that were either not statistically significant or so small that the estimate was unaffected.

The stability of the ratio estimation approach under differing temperature conditions was further examined by separately estimating the full hourly load ratio profile for hot summer days (>75°F) and cool summer days (<75°F). A comparison of these estimates found that the ratios were virtually identical (typical differences of less than 1%) with no pattern to their small discrepancies and a maximum hourly difference of 3.1%. However, the winter profiles showed a consistent difference with temperature. In cold weather (<59°F), the load ratio profile was flatter (lower peaks, and higher lows) than in warm winter weather (>=59°F). This finding is consistent with expectations: when it is cold outside, the thermostat controls the indoor temperature to a narrower range than the "float" that occurs in mild weather. This was also evident from a regression analysis. Dividing the winter into separate "cool" and "warm" period ratios eliminates the temperature dependence.

In summary, a two step approach was selected which estimates daily usage from a regression on temperature and costing period variables and then estimates hourly loads as a simple ratios on daily usage. The ratios are estimated separately for key costing periods (summer weekdays, summer weekends, winter) with winter divided between heating and non-heating modes. This approach reduces the dependence of the estimation process on household and refrigerator characteristics while taking advantage of the consistent load ratio patterns.

Daily Usage Estimation - Group E

Refrigerator usage can be modeled as a linear function of outdoor temperature with an elbow at 59°F. (Proctor and Dutt, 1994) The present analysis used a model that included effects from differences in costing periods (e.g., summer vs. winter, weekdays vs. weekends). Exploratory analysis showed that the model intercept and temperature slope differed somewhat between the summer and the winter. Differences between weekends and weekdays were examined for the summer (when they represent different costing periods). The effect was small and is well represented as a shift in just the model intercept. The final model is:

$$\text{DayUse} = A + B \times \text{Avetemp} + C \times \text{cooltemp} + D \times \text{avetsumm} + E \times \text{summer} + F \times \text{summerwkdy} \quad (1)$$

where:

DayUse = the dependent variable - the annualized use for the day,

A = the intercept coefficient,

B = the daily average temperature coefficient,

Avetemp = the 24 hour average temperature for that day for the nearest weather station,

C = the cooltemp coefficient,
cooltemp = (Avetemp - 59°F) for temperatures below 59°F and 0 elsewhere (cooltemp is the equivalent of heating degree days to the base 59°F),
D = the coefficient of avetsumm,
avetsumm = Avetemp in the summer and 0 in the winter (this accounts for the change in slope in the summer),
E = the coefficient of the dummy variable summer, it is the change in intercept that occurs in the summer,
summer = a 0/1 variable that indicates the data point is in the summer costing period,
F = the coefficient of the dummy variable summerwkdy, it is the change in intercept that occurs in summer weekdays,
summerwkdy = a 0/1 variable which indicates that the data point is in the summer weekday costing period

The response of Group E refrigerator energy consumption to outside temperature for summer weekdays is shown in Figure 1.

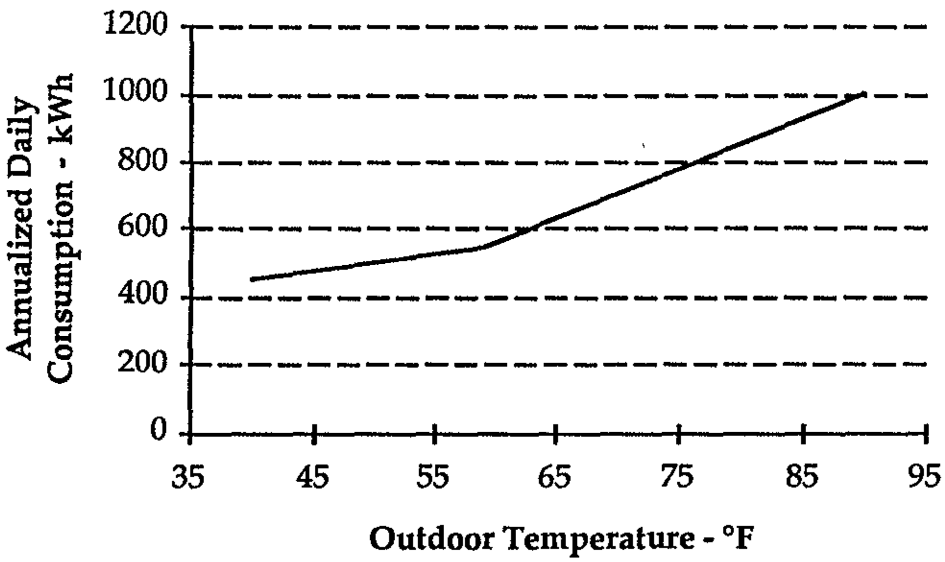

Figure 1. Response of Daily Refrigerator Energy Consumption to Outdoor Temperature (Group E Summer Weekday)

Other variables representing household and/or refrigerator characteristics were examined for possible inclusion in the model. While several of these variables were statistically significant (e.g., occupancy, presence of icemaker, refrigerator volume) they were not included in the final model for several reasons:

- representative data on the same variables was not consistently available for the population (either for PG&E or the particular segment of primary interest -- purchasers of new refrigerators) or in the AMP data set;
- inclusion or exclusion of these variables did not significantly effect the coefficients on the temperature and cost period variables, so their absence apparently does not create problems with bias;
- some of the coefficients were inconsistent with expectations and may be themselves biased.

One of the goals of the analysis was to minimize the number of explanatory variables in the models unless their exclusion biased the remaining coefficients or their inclusion provided valuable insights and/or allowed for correction for some biased sample characteristics to more closely approximate the population of interest. No refrigerator or household characteristics met these criteria in Group E and therefore none were included. This finding is not particularly surprising given that the efficient refrigerator group was specifically selected to minimize the variability of most of these factors (e.g., style, size, efficiency). When the variability of a factor is small, there is little information to determine the effect of that factor on the dependent variable.

Factors not included in the analysis (such as icemaker) are implicitly assumed to occur in the population in the same proportion as they do in the sample.

Daily Usage Estimation - Group T

The Group T refrigerators are much more diverse in terms of size and efficiency because they were sampled to represent typical existing refrigerators. Because of this diversity, the model employed to estimate usage in the Group E performed poorly when applied to Group T. The coefficients were poorly determined and inconsistent with prior expectations. When the same model was estimated using a robust regression procedure (bi-weighted least squares) large discrepancies were found in the coefficients, indicating that the OLS estimates are unstable. In addition, systematic differences were found between Groups E and T in terms of household occupancy and refrigerator volume. These differences needed to be addressed in the analysis.

To improve the model and provide reasonable and stable coefficients while also accounting for differences with the Group E, other explanatory variables were examined. This analysis revealed that when total refrigerator volume was added to the model, stable and reasonable coefficients were found on the temperature variables. The number of occupants was also included in the model to allow adjustment for group differences. In contrast to the efficient group refrigerators, seasonal variables were not found to be of practical or statistical significance and did not affect the other coefficients. The final model for Group T is:

$$DayUse = A + B \times Avetemp + C \times cooltemp + G \times weekday + H \times totvolume + I \times occupants \quad (2)$$

where:

DayUse , Avetemp, and cooltemp as well as coefficients A, B, and C are defined as in Equation 1,

G = the coefficient of the dummy variable weekday, it is the change in intercept that occurs on weekdays,

weekday = a 0/1 variable which indicates that the data point is a weekday,

H = the coefficient of totvolum,

totvolum = the reported total volume for the refrigerator,

I = the coefficient of occupants,

occupants = the reported number of occupants in the household.

The response of Group T refrigerator energy consumption to outside temperature for summer weekdays is shown in Figure 2.

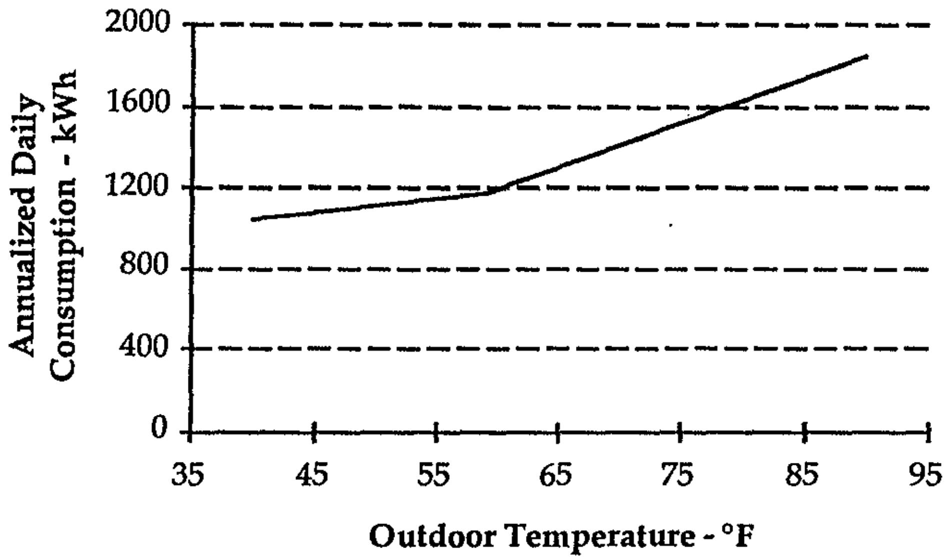

Figure 2. Response of Daily Refrigerator Energy Consumption to Outdoor Temperature (Group T Summer Weekday)

Differences between Group E and Group T are accounted for by using the average total volume and average occupancy from Group E in evaluating the Group T regression equation. The data is normalized to Group E because it is a sample of households that purchased high efficiency rebated refrigerators. This group is assumed to be more representative of rebate recipients than Group T.

Daily Usage Model Estimation and Standard Errors - Both Groups

The daily usage models were estimated using ordinary least squares (OLS) regression. However, the data set did not represent all independent observations, but many observations over time on the same group of refrigerators. The observations on a given refrigerator are correlated due to refrigerator and household-specific characteristics and may also be serially correlated. This situation reduces the efficiency of the OLS estimators compared to an optimal Generalized Least Squares (GLS) approach. Due to the size of the data sets used in the analysis and strong relationships found, this loss in efficiency was not particularly problematic. However, a more significant problem is that OLS provides biased standard errors because of these within-refrigerator correlations. Consistent standard errors can be calculated using an approach described in Appendix A. The OLS coefficients and corrected standard errors are shown in Table 4 for the two models.

Table 4. Regression Coefficients

Group E		Group T	
Coefficient Designation	Coefficient Value [Std. Error]	Coefficient Designation	Coefficient Value [Std. Error]
Constant	-171.82 [84.97]	Constant	-1453.16 [442.34]
Avetemp.	12.37 [1.43]	Avetemp	21.57 [4.54]
Avetsumm	2.42 [1.04]	Occupants	33.17 [26.12]
Summer	-139.62 [70.16]	Totvolume	67.67 [19.41]
Cooltemp.	9.63 [1.53]	Cooltemp	14.22 [8.26]
Summwkdy	-12.28 [3.99]	Weekday	-8.63 [5.90]

Estimating Usage by Costing Period for PG&E's Service Territory in a Typical Weather Year

Pacific Gas and Electric Company's costing periods fall into two seasons, winter and summer. There are three summer costing periods depending on time of day and day of week (weekend/weekday). In the winter there are two costing periods defined by the time of day. The usage by costing period was calculated in a two step process. First, the average daily usage was calculated for four seasonal periods: summer weekdays, summer weekends, winter days with an average temperature above 59°F and winter days with a lower average temperature. Second, the use in particular hours was calculated through a load shape ratio.

The regression models were used to estimate usage by seasonal period for typical PG&E weather using temperature bin data. Based on the weather conditions (TMY's) in each of the PG&E divisions, residential meter weighted temperature bins were established. These bins represent the number of days the outdoor ambient temperature will be in that bin based on typical meteorological data The bins were determined separately for the seasons from May 1 to October 31 and from November 1 to April 31. These bins are reported in Appendix E and illustrated in Figures 3 and 4.

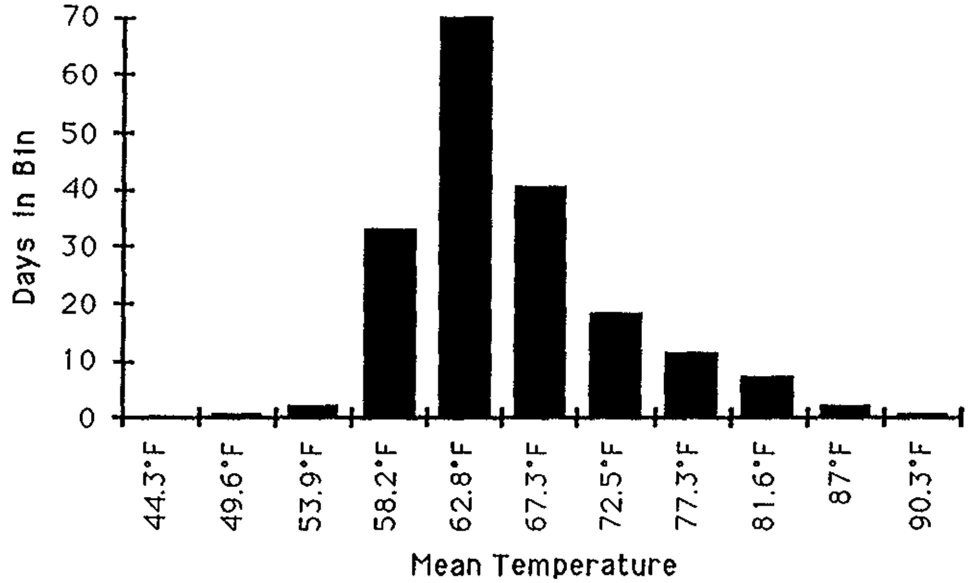

Figure 3. PG&E Residential Meter Weighted Daily Average Temperature Bins for May 1 - October 31 Costing Period

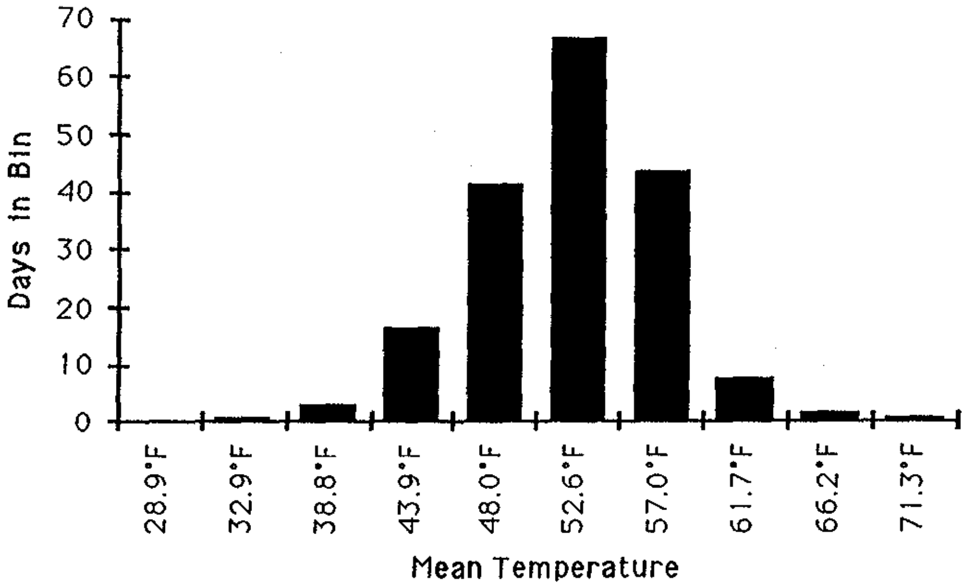

Figure 4. PG&E Residential Meter Weighted Daily Average Temperature Bins for November 1 - April 30 Costing Period

The daily average usage in a seasonal period was estimated by taking a weighted sum of the predicted bin usage (weighted by the number of days in that bin for that costing period).

Standard Error of Usage Rate

The standard error of the weighted average usage rate was calculated using the parameter variance-covariance matrix (estimated as described previously and in Appendix A) to calculate a variance covariance matrix of predicted usage rates by bin. This approach accounts for the correlation in the usage predictions between bins. Appendix B shows the calculations used in matrix form.

Load Shape Ratio Estimation -

The hourly load shapes showed that usage in a given hour (in Watts) is generally proportional to that day's usage, so that

$$Use_{ijk}=R_{ik} * DU_{ij} \qquad (3)$$

where

Use_{ijk} = The load in cost period i, day j, and hour k

R_{ik} = The load ratio in cost period i and hour k

$DU_{ij} = \frac{DailyUse_{ij}}{8.766}$, the average watt draw in period i on day j

$DailyUse_{ij}$ = The annualized use in kWh in period i on day j

$8.766 = \frac{24 \text{ hours/day} * 365.25 \text{ days/year}}{1000 \text{ Watts/kWh}}$

This form is equivalent to a simple linear regression without an intercept term. R can be estimated using a variety of approaches. An inspection of the variance patterns led to using a ratio estimator for R. The ratio estimator for a given hour is calculated as the sum of usage in that hour across all observations in the estimation period (e.g., summer weekdays), divided by the sum of the corresponding daily usage rates. The ratio estimator is equivalent to an optimally weighted least squares analysis with no intercept if the variance of the hourly usage is proportional to the daily usage. Based on the data, this approach appeared more sound than simply calculating the average of the individual hourly ratios.

Separate ratios were calculated for the Group E and Group T refrigerators. For each group, ratios were calculated for summer weekdays, summer weekends, warm winter weather (>=59°F) and cool winter weather (<59°F). The winter was divided into warm and cool periods because the ratios differed systematically between the two, as explained previously. The resulting normalized load shape for Group E on average summer weekdays is shown in Figure 5.

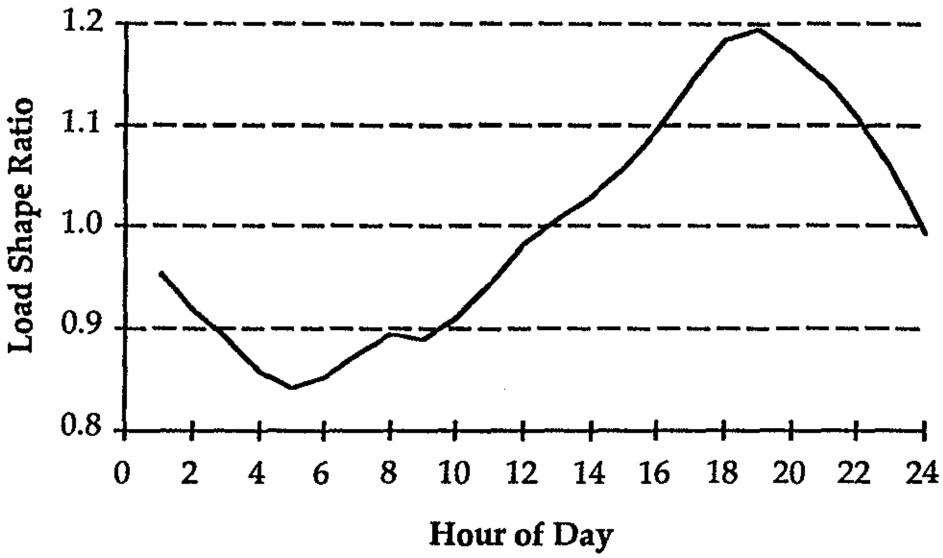

Figure 5. Group E Average Summer Weekday Load Shape Ratio

Standard Errors on the Ratio Estimates

The standard errors for the hourly load shape ratios were calculated from the weighted least squares analysis, using the same approach employed for the daily usage regression models (described in Appendix A) to include the effects of within-refrigerator correlations. The ratios were well-determined, with standard errors of about 1% or less for Group E and about 1.5% for Group T.

Estimates of Hourly Usage on a Peak Day

The usage in a given cost period, on a peak day, in a given hour, is estimated as that hour's ratio for that cost period times the estimated usage for the peak day (a function of temperature and cost period variables as estimated by the daily usage regressions). (From Equation 3)

$$Use_{ipk} = R_{ik} * DU_{ip} \tag{4}$$

where

Use_{ipk} = The load in cost period i, on a peak day, in hour k

R_{ik} = The load ratio in cost period i and hour k

$DU_{ip} = \frac{DailyUse_{ip}}{8.766}$, the average watt draw in period i on a peak day

$DailyUse_{ip}$ = The annualized use in kWh in period i on a peak day

$8.766 = \frac{24\ \text{hours/day} * 365.25\ \text{days/year}}{1000\ \text{Watts/kWh}}$

The standard error of this estimate was calculated as:

$$SE(Use_{ipk})=\sqrt{(se(DU_{ip})^2 + (se(R_{ik}) * DU_{ip})^2)} \qquad (5)$$

where

Use_{ipk} , R_{ik}, and DU_{ip} are defined as in Equation 4.

Refrigerator loads during PG&E system peaks in the summer and winter were calculated by costing periods using the average system-wide outdoor temperatures coincident with the system peaks. The peak days of 1988, 1990 and 1991 (the hottest of 1988 through 1992) were used to determine the Average Peak Temperature for summer period, while the peak days of 1988, 1989, 1990 and 1991 were used for the winter period. The winter peak of 1992 occurred in the spring on an hot day. The peak day system average 24 hour temperature was 80°F in the summer and 44°F in the winter. The summer peak occurred at 4 pm and the winter peak was assessed at 7 pm and 10 pm . The appropriate ratios were applied to the daily usage rates to estimate peak hour usage levels.

Annual Consumption and Peak Draw Calculation for New Refrigerators

Group E results can be used to estimate the annual consumption of new refrigerators. Group E, on the average, is within 2% of the 1993 standard. For new refrigerators of the same size and type as Group E, estimation of annual consumption and load shape from labeled consumption is based on two assumptions. First, that the actual daily energy consumption pattern is proportional to the label use. Second, that the hourly load ratios are the same for the theoretical refrigerator as they were for the refrigerators in Group E.

These are reasonable assumptions (see "Assumption Investigation"), however they should be checked as refrigerators become more efficient.

The calculation of the daily consumption for a new refrigerator in any costing period is given by:

$$DailyUse_{si} = DailyUse_{ei} * L_s / L_e \qquad (6)$$

where

$DailyUse_{si}$ = the average daily consumption for the new refrigerator in period i

$DailyUse_{ei}$ = the average daily consumption for the Group E refrigerators in period i

L_s = the labeled annual consumption for the new refrigerator

L_e = the labeled annual consumption for the Group E refrigerators

The peak watt draw for a new refrigerator in hour k in costing period i is:

$$Use_{sipk} = \frac{DailyUse_{sip}}{8.766} * R_{eik} \qquad (7)$$

where

Use_{sipk} = the new refrigerator peak electrical load in period i in hour k.

$DailyUse_{sip}$ = the daily consumption for the new refrigerator in period i on a peak day

R_{eik} = the ratio of the electrical load of the Group E refrigerators in period i in hour k to the average watt draw for that day.

The two assumptions, energy consumption proportional to label and hourly load ratios the same as Group E, are also necessary to apply Group E data to refrigerators of different size or type. These assumptions again seem reasonable, however they too should be validated for other refrigerator styles.

These estimates will only apply to PG&E's service territory since they have been normalized to temperature bins that represent their residential customer distribution.

Assumption Investigation

The assumption that hourly load ratios are the same as Group E for other new refrigerators with differing efficiency was tested with data from part one of this study. The load ratios for the lesser efficient group in that portion of the study (referred to as Group S) were calculated and were an extremely close match with the Group E ratios as shown in Figure 6.

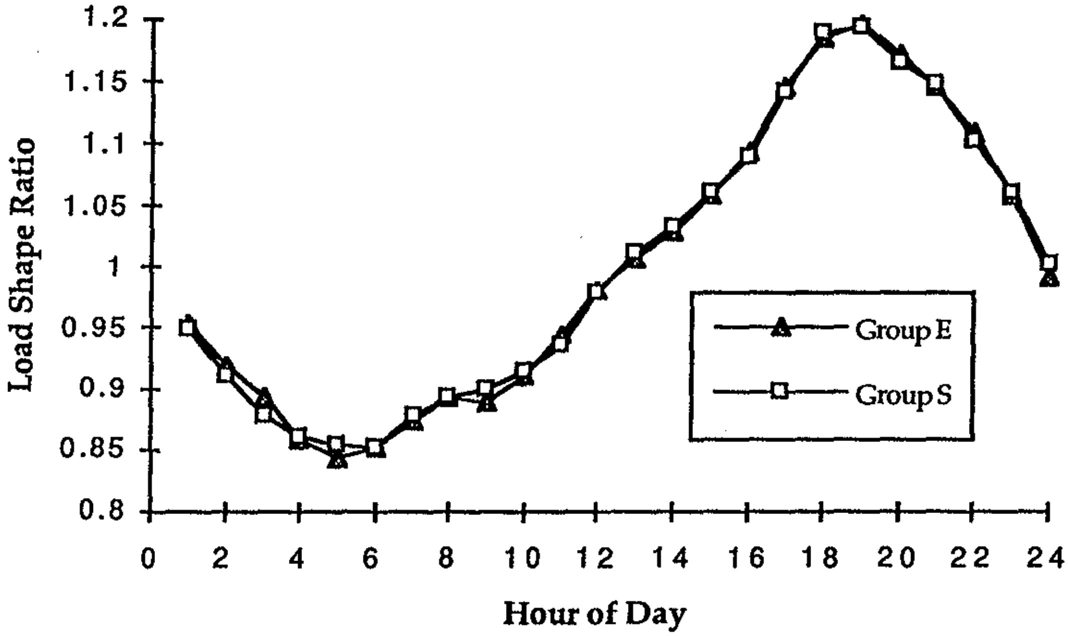

Figure 6. Load Ratio Comparison between Efficiency Groups

IV. RESULTS

Detailed results for Group E and T as well as for prototypical "standard", "rebated", and "typical" refrigerators are presented in Appendix C. The results are summarized in this section.

Refrigerator Descriptions

Group E consists of 120 refrigerators[2] that, on average, slightly exceed the 1993 federal standard. The standard for top freezer, automatic defrost refrigerators with an adjusted volume of 22.38 cubic feet is 709 kWh (16*adjusted volume + 351 kWh). The labeled annual consumption for these refrigerators is 695 kWh. In the PG&E service territory, these refrigerators have an annual consumption of 599 kWh (13.8% less than labeled consumption).

Group T consists of 40 refrigerators[3] that, on average, are 11.9 years old . In the PG&E service territory, these refrigerators have an annual consumption of 1301 kWh. The AMP refrigerators reported on in the 1985-1986 Pacific Gas and Electric Company Residential Appliance Load Study (Brodsky and McNicoll, 1987) were larger, slightly older and contained side by side units. The 1985-1986 units consumed more energy (1980 kWh) than these 40 refrigerators. The 1985-1986 results were not normalized to typical weather data. Group T refrigerator usage compares favorably with the 1990 Residential Appliance Saturation Survey Estimate of 1255 kWh (XENERGY, 1992). Savings estimates based on Group T will be conservative (predict less savings) compared to an estimate using the 1985-1986 AMP sample.

Refrigerator Configurations for Calculations

All of the prototype refrigerators are of the same size and configuration. They all have an adjusted volume of 22.79[4] cubic feet, all are top freezer automatic defrost refrigerators without through the door features. The Federal standard for refrigerators of this type and size is 716 kWh. These refrigerators are all installed in homes with 2.54 occupants.

The "standard" refrigerator is a new theoretical refrigerator that just meets the federal standard . Its labeled consumption is 716 kWh. Its consumption and load shape are calculated as noted in "Estimation for New Refrigerators with Label Values Differing from Group E".

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[2] In homes with an average of 2.54 occupants which is assumed to be representative of high efficiency rebate customers (which was the source of the sample).

[3] In homes with an average of 3.1 occupants and a total volume of 19.7 cubic feet.

[4] The refrigerator size used in PG&E's program calculations.

The "rebated" refrigerator is a new theoretical refrigerator that has a labeled consumption 20% less than the Federal standard (573 kWh). Its consumption and load shape are calculated in the same manner as the "standard" refrigerator.

The "typical" refrigerator is a prototypical existing refrigerator 12 year old, with a total volume of 19.3 cubic feet, which is the equivalent of an adjusted volume of 22.79 cubic feet. Its consumption and load is calculated as noted in "Estimation for Old Refrigerators with Characteristics Differing from Group T".

Load Shape Effects

The load shape of the older Group T refrigerators is flatter than that of the new Group E refrigerators. This is illustrated in Figure 7, where the Group T refrigerators peak consumption is 113% of their average consumption on that day. compared to 120% for Group E. Some refrigerators in Group T run nearly continuously in the summer. This contributes to the flatter load shape.

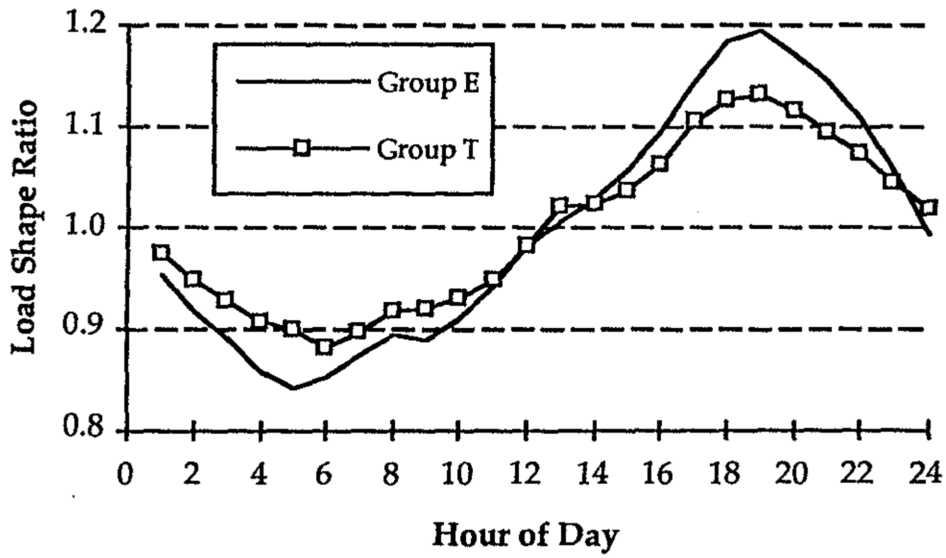

Figure 7 Summer Weekday Load Shape Ratios - Group E and Group T (New and Old Refrigerators)

The summer peak day consumption for each prototypical refrigerator is combined with the appropriate load ratio displayed in Figure 7. The results are the peak day load shapes of "Standard", "Rebated" and "Typical" refrigerators shown in Figure 8.

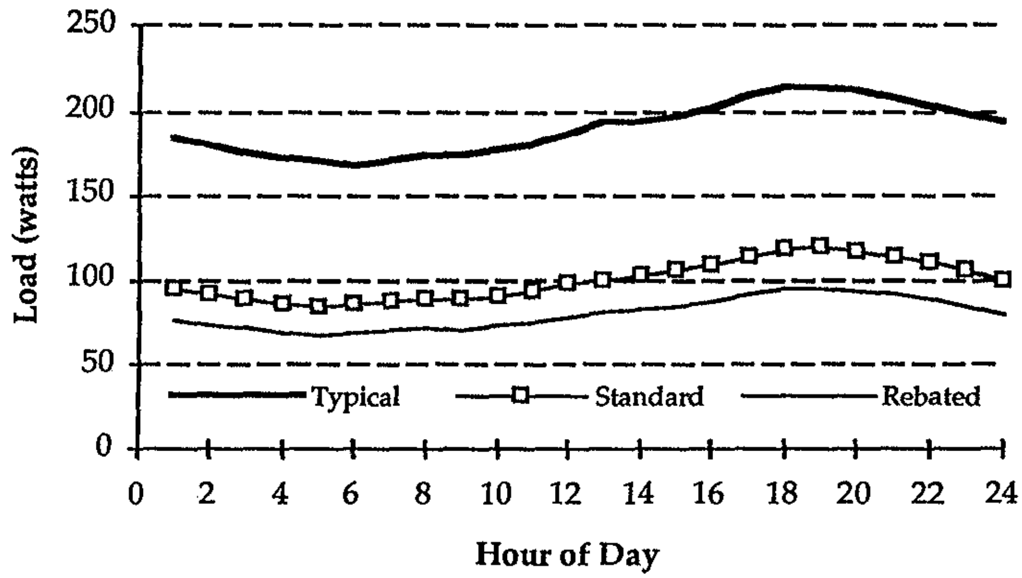

Figure 8. Summer Peak Day Load Shape - Typical, Standard, and Rebated Refrigerators

Validity of Peak Estimates

In order to test the validity of the peak estimates, the consumption of the AMP refrigerators on the peak day of 1992 was compared to consumption projected by this analysis. The result is shown in Figure 9.

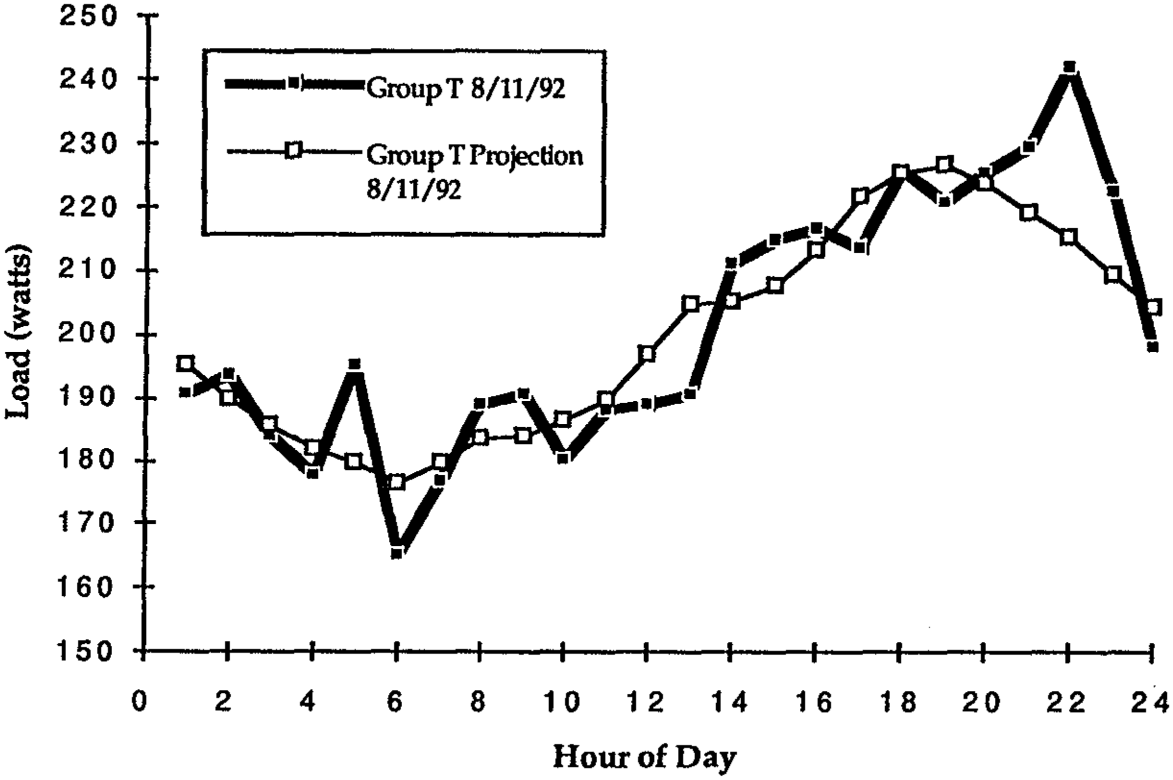

Figure 9. Predicted vs. Metered Peak Day Load Curves

Most metered sites did not have data for the peak day during Group E metering (many of the meters overwrote the data) 16 peak like days were selected and metered results were compared to predicted loads. Both the load shape and annualized daily consumption were accurately predicted. For those days the annualized average consumption was predicted to be 869 kWh while the actual consumption averaged 856 kWh with a range from 825 to 902.

Calculations and Adjustment Factors

This study produced factors to estimate the actual annual energy savings, energy savings by cost period, and peak watt reduction by cost period for both new and existing refrigerators. The savings calculations for new refrigerators are:

1) Subtract the labeled usage of the baseline refrigerator from the labeled consumption of the more efficient unit.
2) Multiply the difference in labeled consumption from Step 1 by .862 to obtain the Actual Annual kWh Savings in PG&E's service territory.
3) Multiply the Actual Annual kWh Savings by the Percent of Annual kWh adjustment factors in Table 5 to obtain the kWh savings in each costing period.
4) Multiply the Actual Annual kWh Savings by the $\frac{\text{Peak Watt Reduction}}{\text{Actual Ann. kWh Savings}}$ adjustment factors in Table 5 to obtain the peak watt reduction in each costing period.

The adjustment factors for new refrigerators are contained in Table 5.

Table 5. Adjustment Factors for New Refrigerators			
Difference in Labeled Consumption = (Labeled Consumption of Rebated Refrigerator - Labeled Consumption of Baseline Refrigerator)			
$\frac{\text{Actual Annual kWh Savings}}{\text{Difference in Labeled kWh}} = .862$			
Costing Period	**Hour**	$\frac{\textbf{Peak Watt Reduction}}{\textbf{Actual Ann. kWh Savings}}$	**Percent of Annual kWh**
Summer On Peak	16	0.179	10.65%
Summer Partial Peak	19	0.196	12.0%
Summer Off Peak	19	0.197	32.5%
Winter Partial Peak	19	0.115	25.7%
Winter Off Peak	22	0.109	19.15%

To calculate the energy savings and peak reduction for the replacement of an existing refrigerator, the energy consumption and peak load in each costing period must first be calculated for each refrigerator as described in "Estimation for New Refrigerators with Label Values Differing from Group E" and "Estimation of Old Refrigerators with Characteristics Differing from Group T". The energy savings and peak reduction for each costing period are then calculated by subtracting the values for the replacement unit from the values for the existing refrigerator.

Estimation of Old Refrigerators with Characteristics Differing from Group T

To calculate the energy costing period consumption and peak energy use of an existing refrigerator:

1) Estimate the annual energy consumption of the existing refrigerator by substituting the total volume and household occupancy into appropriate variables in Equation 8 (Equation 2 reduced to PG&E specific values).

$$\text{Actual Annual Consumption} = -134.8 + 67.67 * \text{totvolum} + 33.17 * \text{occupants} \quad (8)$$

where:

-134.8 = the intercept term (kWh)

67.67 = the coefficient of totvolum (kWh/cubic foot)

totvolum = the reported total volume for the refrigerator (cubic feet)

33.17 = the coefficient of occupants (kWh/occupant)

occupants = the reported number of occupants in the household.

2) Multiply the Actual Annual Consumption by the Percent of Annual kWh adjustment factors in Table 6 to obtain the kWh consumption in each costing period.

3) Multiply the Actual Annual Consumption by the $\frac{\text{Peak Watt Draw}}{\text{Actual Ann. Consumption}}$ adjustment factors in Table 6 to obtain the peak watt draw in each costing period.

Table 6. Adjustment Factors for Old Refrigerators

Costing Period	Hour	Peak Watt Draw / Actual Ann. Consumption	Percent of Annual kWh
Summer On Peak	16	0.160	10.3%
Summer Partial Peak	19	0.170	11.6%
Summer Off Peak	19	0.171	32.5%
Winter Partial Peak	19	0.110	25.8%
Winter Off Peak	22	0.103	19.8%

Estimation for New Refrigerators with Label Values Differing from Group E

1) The annual energy consumption of the new refrigerator is estimated by substituting labeled energy consumption into Equation 9 (Equation 6 summed over all costing periods).

$$\text{Annual Energy Consumption} = \frac{599}{695} * L_s \quad (9)$$

where

599 = the annual consumption for Group E refrigerators (kWh)

695 = the labeled annual consumption for Group E refrigerators (kWh)

L_S = the labeled annual consumption for the new refrigerator

2) Multiply the Annual Energy Consumption by the Percent of Annual kWh adjustment factors in Table 5 to obtain the kWh consumption in each costing period.

3) Multiply the Annual Energy Consumption by the $\frac{\text{Peak Watt Reduction}}{\text{Actual Ann. kWh Savings}}$ adjustment factors in Table 5 to obtain the peak watt draw in each costing period.

Energy Consumption, Peak Loads, Energy Savings, and Peak Reduction

The refrigerator configuration and the estimated annual energy consumption for the two metered groups and the three prototype refrigerators are shown in Table 7.

Table 7. Refrigerator Configuration and Estimated Annual Energy Consumption

	Group E	Group T	Standard	Rebated	Typical
Household Occupancy	2.54	3.1	2.54	2.54	2.54
Adjusted Volume (cu. ft.)	22.38	a	22.79	22.79	22.79[b]
Federal Standard (kWh for that Adjusted Volume)	709	NA	716	716	716
Labeled Consumption (kWh)	695	NA	716	573	NA
Estimated Annual Consumption (kWh)	**599**	**1301**	**617**	**493**	**1255**

a. Total volume is 19.7 cubic feet
b. Total volume is 19.3 cubic feet

Table 8 lists the estimated peak watt draw for Groups E and T as well as the prototype refrigerators.

Table 8. Peak Watt Draw by Costing Period[a]

Peak Hour	Group E	Group T	Standard	Rebated	Typical
Summer On Peak[b] 4 PM	107 [2.4]	206 [13.2]	110 [2.4]	88 [2.4]	201 [13.2]
Summer Partial Peak[c] 7 PM	117 [2.4]	220 [13.1]	121 [2.5]	97 [2.4]	214 [13.1]
Summer Off Peak[d] 7 PM	118 [2.5]	220 [13.1]	121 [2.5]	97 [2.4]	214 [13.1]
Winter Partial Peak[e] 7 PM	69 [1.5]	143 [9.4]	71 [1.5]	57 [1.5]	138 [9.3]
Winter Off Peak[f] 10 PM	65 [1.5]	135 [9.3]	76 [1.5]	54 [1.5]	130 [9.3]

a. Numbers in brackets [] are standard errors
b. May 1 to October 31, 12 noon - 6 pm, weekdays
c. May 1 to October 31, 8:30 am-12 noon and 6:00 pm-9:30 pm, weekdays
d. May 1 to October 31, Other
e. November 1 to April 30, 8:30 am - 9:30 pm
f. November 1 to April 30, Other

As shown in Table 9 there are significant energy savings and peak reductions available when higher efficiency "rebated" refrigerators replace lower efficiency "typical" or "standard" units. In PG&E's service territory, 763 kWh is saved by replacing a "typical" existing refrigerator with a new high efficiency "rebated" refrigerator. This replacement will also reduce the summer coincident peak by 113 watts. In addition, the "rebated" refrigerator will use 123 kWh less than a theoretical refrigerator that just meets the standard. The associated peak reduction is 22 watts.

Table 9 Annual Energy Savings and Peak Reduction by Costing Period[a]			
	Typical Replaced by Rebated	Typical Replaced by Standard	Rebated Chosen over Standard
Annual Energy Savings (kWh)	763	638	123
Summer On Peak[b] (Watt Reduction at 4 PM)	113	90	22
Summer Partial Peak[c] (Watt Reduction at 7 PM)	117	93	24
Summer Off Peak[d] (Watt Reduction at 7 PM)	117	93	24
Winter Partial Peak[e] (Watt Reduction at 7 PM)	81	66	14
Winter Off Peak[f] (Watt Reduction at 10 PM)	76	63	13

a. These figures may be slightly different from differences within Tables 7 and 8 due to rounding.

Conclusions

Based on the PG&E refrigerator metering study reasonable estimations of energy savings and peak reduction impacts can be made for:

1) the selection of a more efficient new refrigerator over a less efficient new refrigerator of the same size and style.

2) the replacement of an existing refrigerator with a new refrigerator of the same size and style.

The labeled energy consumption of refrigerators is based on a 90°F room temperature test. This high temperature produces higher energy consumption than actually occurs in the homes in PG&E's service territory. The metering results on rebated customers homes show that the overprediction of consumption (and savings) is 13.8%.

In the selection of new refrigerators the net energy savings and peak reduction will depend on the baseline refrigerator and net-to-gross effects. For an existing refrigerator, the energy consumption and peak use calculated from the equations and factors in this report can be used as a conservative baseline.

Recommendations

The applicability of this data is dependent on two relationships:

1) the relationship between the daily consumption and the load by hour - the load shape ratios,
2) the relationship between the yearly consumption and the labeled consumption.

It is recommended that these two relationships now be tested on a smaller sample of new refrigerators of a variety of sizes and types. Thereafter these relationships should be checked as standards change, or every other year to capture design changes. With higher standards, the trend toward higher cabinet efficiency is likely to continue. As a result, occupant effects will become a larger portion of the annual consumption. This shift could effect both of these relationships.

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APPENDIX A - STANDARD ERROR ESTIMATION

Consistent Standard Error Estimation Using White's Method on Grouped Data

A method described by White (1980) was used to estimate appropriate standard errors for the daily usage models and the hourly ratio estimates. When applied to "grouped" data such as in this data set, White's approach estimates standard errors which account for the within-refrigerator correlations. Essentially, the approach involves estimating the error variance-covariance matrix using the observed structure in the residuals, grouped by refrigerator (including calculating off-diagonal elements within refrigerators). The variance covariance matrix of the parameters is then calculated using this matrix in the standard equation for estimating OLS standard errors when the residual are correlated and/or heteroscedastic:

$$(X'X)^{-1}X'VX(X'X)^{-1}$$

where V is the estimated variance covariance matrix of the residuals

APPENDIX B - CALCULATION DETAILS

Calculation of weighted average usage rates and standard errors for costing periods and peaks from bin data, regression coefficients, and corrected parameter variance covariance matrix.

Weighted Annualized Usage & Standard Errors / Confidence Intervals for bin analysis

Set up bins and figure out weights:

$$Tbins := \begin{bmatrix} 44.3 & 28.9 & 28.9 \\ 49.6 & 32.9 & 32.9 \\ 53.9 & 38.8 & 38.8 \\ 58.2 & 43.9 & 43.9 \\ 62.8 & 48.0 & 48.0 \\ 67.3 & 52.6 & 52.6 \\ 72.5 & 57.0 & 57.0 \\ 77.3 & 61.7 & 61.7 \\ 81.6 & 66.2 & 66.2 \\ 87.0 & 71.3 & 71.3 \\ 90.3 & 77.5 & 77.5 \end{bmatrix} \quad Daybins := \begin{bmatrix} .055 & .02 & 0 \\ .28 & .36 & 0 \\ 1.83 & 3.03 & 0 \\ 32.81 & 16.54 & 0 \\ 69.73 & 41.18 & 0 \\ 40.27 & 66.59 & 0 \\ 18.39 & 43.8 & 0 \\ 11.45 & 0 & 7.70 \\ 6.91 & 0 & 1.49 \\ 2.19 & 0 & .29 \\ 0.85 & 0 & 0 \end{bmatrix}$$

\# periods   \# bins

$k := 1..3 \qquad e := 1..11$

$$SumDays_k := \sum_e Daybins_{e,k}$$

Bin Weights

$$Wbins_{e,k} := \frac{Daybins_{e,k}}{SumDays_k}$$

$i := 1..6 \qquad j := 1..6$

Set up various inputs to X matrices to predict usage by bin

Temperature Inputs $\quad AveT_{e,k} := Tbins_{e,k} \qquad CoolT_{e,k} := if(Tbins_{e,k} < 59, 59 - Tbins_{e,k}, 0)$

Occupants, Volume, etc. $\quad Occ := 2.54 \qquad Vol := 18.97$

Misc constants for dummy vars $\quad One_e := 1 \qquad One3_{e,k} := 1 \qquad Zero3_{e,k} := 0 \qquad Wwkdy_e := \frac{5}{7}$

Combine Avetemp & Cooltemp by period

$Tsum := augment(AveT^{<1>}, CoolT^{<1>})$

$Twincl := augment(AveT^{<2>}, CoolT^{<2>}) \qquad Twinwm := augment(AveT^{<3>}, CoolT^{<3>})$

Set up matrix of AMP Xs for each bin (avetemp,cooltemp,weekday,total vol, occup,1)

$VolOccOne_{e,1} := Vol \qquad VolOccOne_{e,2} := Occ \qquad VolOccOne_{e,3} := 1$

Summer Weekday $\quad Aswkd := augment(Tsum, augment(One, VolOccOne))$

Summer Weekend $\quad Aswke := Aswkd \qquad Aswke_{e,3} := 0$

Winter Cool $\quad Awcool := augment(Twincl, augment(Wwkdy, VolOccOne))$

Winter Warm $\quad Awwarm := augment(Twinwm, augment(Wwkdy, VolOccOne))$

Set up matrix of Efficient grp Xs (avetemp,cooltemp,AveTsummer,Summer,SummWkday,1)

Summer Weekday $\quad Eswkd := augment(Tsum, augment(AveT^{<1>}, One3))$

Summer Weekend $\quad Eswke := Eswkd \qquad Eswke_{e,5} := 0$

Winter Cool $\quad Ewcool := augment(Twincl, (augment(Zero3, One)))$

Winter Warm $\quad Ewwarm := augment(Twinwm, (augment(Zero3, One)))$

Set up formulas for calculation of Usage and Variance by Bin, and Weighted Average Usage and it's Variance based on the Variance-Covariance Matrix of the predicted usage rates for the bins

Convert triangular cov mat to rect. $Vmat(V) := if(i>j, V_{i,j}, V_{j,i})$

PU= Predicted Usage (for bins) $PU(X,b) := X \cdot b$

UAve = bin-weighted average usage $UAve(X,b,s) := {Wbins^{<s>}}^{T} \cdot X \cdot b$

VPred=Var-Covar of PU, incl. bin covar $VPred(X,V) := X \cdot V \cdot X^{T}$

VUse=Variance of UAve $VUse(X,V,s) := {Wbins^{<s>}}^{T} \cdot VPred(X,V) \cdot Wbins^{<s>}$

SEU=Std Err of UAve $SEU(X,V,s) := \sqrt{VUse(X,V,s)_{1,1}}$

NOTE: Usage rates are in annualized kWh, average watts is this figure divided by 8.76

Efficient Group data inputs

Model Coefficients: $$Ebeta := \begin{bmatrix} 12.3731 \\ 9.62857 \\ 2.4213 \\ -139.617 \\ -12.2838 \\ -171.823 \end{bmatrix}$$

Summer Peak $$ESpk := \begin{bmatrix} 79.97 \\ 0 \\ 79.97 \\ 1 \\ 1 \\ 1 \end{bmatrix}$$

Winter Peak $$EWpk := \begin{bmatrix} 43.65 \\ 15.35 \\ 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

Var-Covar Matrix - lower triangle

$$EVtri := \begin{bmatrix} 2.0316 & 0 & 0 & 0 & 0 & 0 \\ 2.0871 & 2.3419 & 0 & 0 & 0 & 0 \\ -.82640 & -.82516 & 1.0714 & 0 & 0 & 0 \\ 39.7955 & 38.3415 & -70.8643 & 4922.7 & 0 & 0 \\ 1.5434 & 1.56778 & -.4150 & -.550755 & 15.9282 & 0 \\ -120.03 & -123.837 & 50.521 & -2480.06 & -85.6165 & 7220.55 \end{bmatrix}$$

$EV_{i,j} := Vmat(EVtri)$

RESULTS for Efficient group refrigerators:

	Summer Weekday	Summer Weekend
AveUse	$UAve(Eswkd, Ebeta, 1) = 652.24$	$UAve(Eswke, Ebeta, 1) = 664.52$
StdErr	$SEU(Eswkd, EV, 1) = 14.75$	$SEU(Eswke, EV, 1) = 14.99$
	Winter Cool	Winter Warm
AveUse	$UAve(Ewcool, Ebeta, 2) = 537.58$	$UAve(Ewwarm, Ebeta, 3) = 603.98$
StdErr	$SEU(Ewcool, EV, 2) = 11.50$	$SEU(Ewwarm, EV, 3) = 12.47$

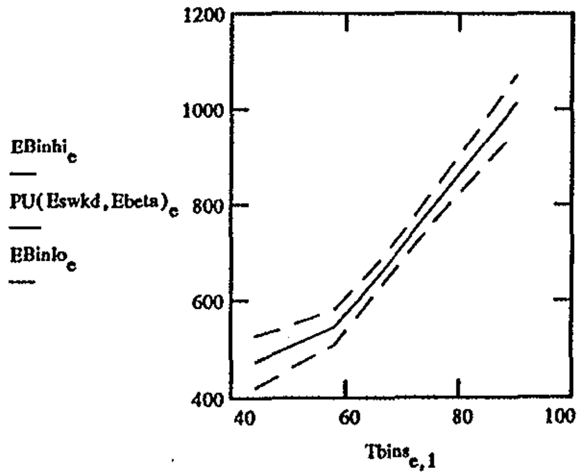
Peak Impacts	Summer	Winter
	$SPeakh := PU(ESpk, Ebeta)$	$WPeakh := PU(EWpk, Ebeta)$
	$SESpk := \sqrt{VPred(ESpk^{T}, EV)_{1,1}}$	$SEWpk := \sqrt{VPred(EWpk^{T}, EV)_{1,1}}$
Day's Usage	$SPeakh = 859.38$	$WPeakh = 516.06$
Std Err	$SESpk = 19.88$	$SEWpk = 12.63$

Confidence Intervals of usage for Summer Weekdays, by bin:

$$ECIBin_e := 1.96 \cdot \sqrt{VPred(Eswkd, EV)_{e,e}}$$

$EBinhi := PU(Eswkd, Ebeta) + ECIBin$ $\quad$ $EBinlo := PU(Eswkd, Ebeta) - ECIBin$

Efficient Group Usage by temperature bin - summer weekday model



AMP data inputs

Model Coefficients:	Summer Peak	Winter Peak
$Abeta := \begin{bmatrix} 21.5706 \\ 14.2157 \\ -8.6296 \\ 67.667 \\ 33.171 \\ -1453.16 \end{bmatrix}$	$ASpk := \begin{bmatrix} 79.97 \\ 0 \\ 1 \\ Vol \\ Occ \\ 1 \end{bmatrix}$	$AWpk := \begin{bmatrix} 43.65 \\ 15.35 \\ 1 \\ Vol \\ Occ \\ 1 \end{bmatrix}$

Var-Covar matrix from White method - only lower triangle needed, expanded by symmetry

$$AVtri := \begin{bmatrix} 20.6565 & 0 & 0 & 0 & 0 & 0 \\ 34.1041 & 68.2339 & 0 & 0 & 0 & 0 \\ -.088548 & 2.89684 & 34.8144 & 0 & 0 & 0 \\ -8.9961 & 3.9861 & 21.0432 & 376.637 & 0 & 0 \\ 9.325 & 5.24371 & -1.0531 & -248.225 & 682.068 & 0 \\ -1219.75 & -2516.23 & -399.88 & -5942.53 & 2528.35 & 195663 \end{bmatrix}$$

$$AV_{i,j} := Vmat(AVtri)$$

RESULTS for AMP Group Refrigerators, using efficient group's occupancy & volume:

	Summer Weekday	Summer Weekend
AveUse	UAve(Aswkd, Abeta, 1) = 1329.12	UAve(Aswke, Abeta, 1) = 1337.75
StdErr	SEU(Aswkd, AV, 1) = 92.64	SEU(Aswke, AV, 1) = 92.54
	Winter Cool	Winter Warm
AveUse	UAve(Awcool, Abeta, 2) = 1126.02	UAve(Awwarm, Abeta, 3) = 1261.07
StdErr	SEU(Awcool, AV, 2) = 82.99	SEU(Awwarm, AV, 3) = 94.28

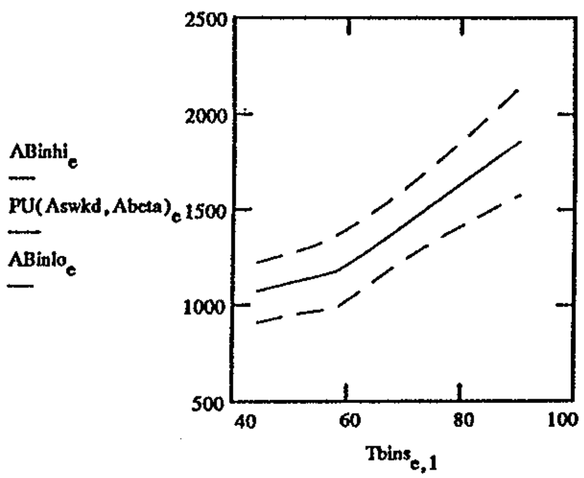
Peak Impacts	Summer	Winter
	SPeakh := PU(ASpk, Abeta)	WPeakh := PU(AWpk, Abeta)
	$SESpk := \sqrt{VPred\left(ASpk^{T}, AV\right)_{1,1}}$	$SEWpk := \sqrt{VPred\left(AWpk^{T}, AV\right)_{1,1}}$
Day's Usage	SPeakh = 1631.11	WPeakh = 1065.88
Std Err	SESpk = 112.19	SEWpk = 80.48

Confidence Intervals of usage for Summer Weekdays, by bin:

$$ACIBin_{e} := 1.96 \cdot \sqrt{VPred(Aswkd, AV)_{e,e}}$$

ABinhi := PU(Aswkd, Abeta) + ACIBin   ABinlo := PU(Aswkd, Abeta) – ACIBin

AMP Group Usage by temperature bin - summer weekday model



APPENDIX C - DETAILED RESULTS

The study results are detailed in this section. It contains regression coefficients for Groups E and T, tables of adjustment factors for both new and old refrigerators, a table of refrigerator characteristics and estimated annual consumption, a table of peak watt draw by costing period, and refrigerator load curves.

Table 10. Regression Coefficients

Group E [a]		Group T [b]	
Coefficient Designation	Coefficient Value [Std. Error]	Coefficient Designation	Coefficient Value [Std. Error]
Constant	-171.82 [84.97]	Constant	-1453.16 [442.34]
Avetemp.	12.37 [1.43]	Avetemp	21.57 [4.54]
Avetsumm	2.42 [1.04]	Occupants	33.17 [26.12]
Summer	-139.62 [70.16]	Totvolume	67.67 [19.41]
Cooltemp.	9.63 [1.53]	Cooltemp	14.22 [8.26]
Summwkdy	-12.28 [3.99]	Weekday	-8.63 [5.90]

a. Group E consists of 120 refrigerators that, on average, slightly exceed the 1993 federal standard. They are in homes with an average of 2.54 occupants. The labeled annual consumption for these refrigerators is 695 kWh. In the PG&E service territory, these refrigerators have an annual consumption of 599 kWh (13.8% less than labeled consumption).

b. Group T consists of 40 refrigerators that, on average, are 11.9 years old. They are in homes with an average of 3.1 occupants and their average total volume is 19.7 cubic feet. In the PG&E service territory, these refrigerators have an annual consumption of 1301 kWh.

Table 11. Adjustment Factors for New Refrigerators			
Difference in Labeled Consumption = (Labeled Consumption of Rebated Refrigerator - Labeled Consumption of Baseline Refrigerator)			
$\frac{\text{Actual Annual kWh Savings}}{\text{Difference in Labeled kWh}} = .862$ [a]			
Costing Period	**Hour**	$\frac{\textbf{Peak Watt Reduction}}{\textbf{Actual Ann. kWh Savings}}$ [b]	**Percent of Annual kWh**
Summer On Peak[c]	16	0.179	10.65%
Summer Partial Peak[d]	19	0.196	12.0%
Summer Off Peak[e]	19	0.197	32.5%
Winter Partial Peak[f]	19	0.115	25.7%
Winter Off Peak[g]	22	0.109	19.15%

a. Metered refrigerator data shows that new refrigerators in homes similar to those in Group E consume 13.8% less than labeled consumption. Similarly the difference between two new refrigerators in those homes is 13.8% less than the difference in labeled consumption.
b. This factor is used to convert annual kWh savings to peak reduction for new refrigerators. It is also used to convert annual kWh usage to peak watt draw for new refrigerators.
c. May 1 to October 31, 12 noon - 6 pm, weekdays
d May 1 to October 31, 8:30 am-12 noon and 6:00 pm-9:30 pm, weekdays
e. May 1 to October 31, Other
f. November 1 to April 30, 8:30 am - 9:30 pm
g November 1 to April 30, Other

Table 12. Adjustment Factors for Old Refrigerators			
Costing Period	**Hour**	$\frac{\textbf{Peak Watt Draw}}{\textbf{Actual Ann. Consumption}}$ [a]	**Percent of Annual kWh**
Summer On Peak	16	0.160	10.3%
Summer Partial Peak	19	0.170	11.6%
Summer Off Peak	19	0.171	32.5%
Winter Partial Peak	19	0.110	25.8%
Winter Off Peak	22	0.103	19.8%

a. This factor is used to convert annual kWh usage to peak watt draw for old refrigerators.

Table 13. Refrigerator Configuration and Estimated Annual Energy Consumption					
	Group E	Group T	Standard[a]	Rebated[b]	Typical[c]
Household Occupancy	2.54	3.1	2.54	2.54	2.54
Adjusted Volume[f] (cu. ft.)	22.38	d	22.79	22.79	22.79[e]
Federal Standard[g] (kWh for that Adjusted Volume)	709	NA	716	716	716
Labeled Consumption[h] (kWh)	695	NA	716	573	NA
Estimated Annual Consumption (kWh)	**599**	**1301**	**617**	**493**	**1255**

a. The "standard" refrigerator is a theoretical refrigerator that just meets the Federal standard and is of the same size and type as refrigerators in Group E. Its consumption and load shape are calculated based on regression coefficients and load shape ratios from Group E.
b. The "rebated" refrigerator is a theoretical refrigerator that has a labeled consumption 20% less than the Federal standard and is of the same size and type as refrigerators in Group E. Its consumption and load shape are calculated in the same manner as the "standard" refrigerator.
c. The "typical" refrigerator is a theoretical refrigerator that represents average refrigerators and is of the same size as refrigerators in Group E. Its consumption and load shape are calculated based on regression coefficients and load shape ratios from Group T.
d. Total volume is 19.7 cubic feet
e. Total volume is 19.3 cubic feet
f. Adjusted volume is defined as the fresh volume + 1.63 * freezer volume
g. The Federal standard for top freezer, automatic defrost refrigerators is (16*adjusted volume + 351 kWh).
h. The labeled consumption is determined by the DOE test procedure

Table 14. Peak Watt Draw by Costing Period[a]					
Peak Hour	Group E	Group T	Standard	Rebated	Typical
Summer On Peak[b] 4 PM	107 [2.4]	206 [13.2]	110 [2.4]	88 [2.4]	201 [13.2]
Summer Partial Peak[c] 7 PM	117 [2.4]	220 [13.1]	121 [2.5]	97 [2.4]	214 [13.1]
Summer Off Peak[d] 7 PM	118 [2.5]	220 [13.1]	121 [2.5]	97 [2.4]	214 [13.1]
Winter Partial Peak[e] 7 PM	69 [1.5]	143 [9.4]	71 [1.5]	57 [1.5]	138 [9.3]
Winter Off Peak[f] 10 PM	65 [1.5]	135 [9.3]	76 [1.5]	54 [1.5]	130 [9.3]

a. Numbers in brackets [] are standard errors
b. May 1 to October 31, 12 noon - 6 pm, weekdays
c. May 1 to October 31, 8:30 am-12 noon and 6:00 pm-9:30 pm, weekdays
d. May 1 to October 31, Other
e. November 1 to April 30, 8:30 am - 9:30 pm
f. November 1 to April 30, Other

Table 15 Annual Energy Savings and Peak Reduction by Costing Period[a]			
	Typical Replaced by Rebated	Typical Replaced by Standard	Rebated Chosen over Standard
Annual Energy Savings (kWh)	763	638	123
Summer On Peak (Watt Reduction at 4 PM)	113	90	22
Summer Partial Peak (Watt Reduction at 7 PM)	117	93	24
Summer Off Peak (Watt Reduction at 7 PM)	117	93	24
Winter Partial Peak (Watt Reduction at 7 PM)	81	66	14
Winter Off Peak (Watt Reduction at 10 PM)	76	63	13

a. These figures may be slightly different from differences within other tables due to rounding.

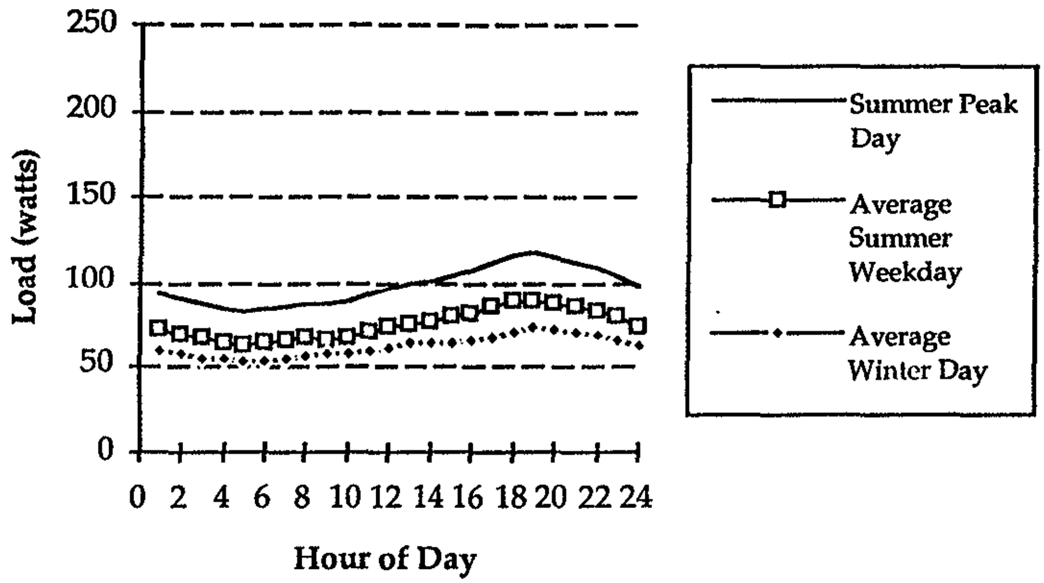


Figure 10. Group E Load Curves

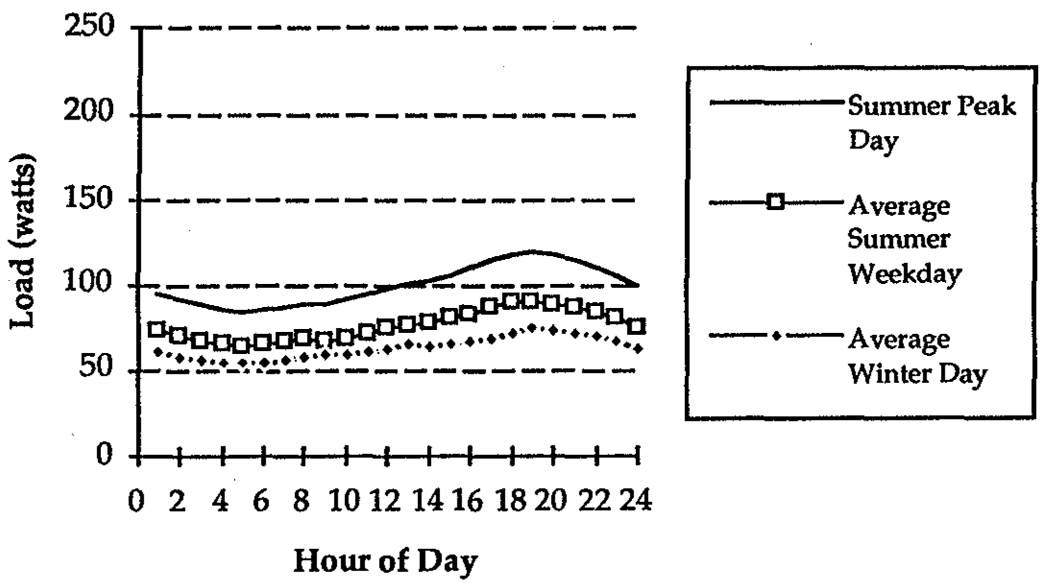


Figure 11. Standard Refrigerator Load Curves

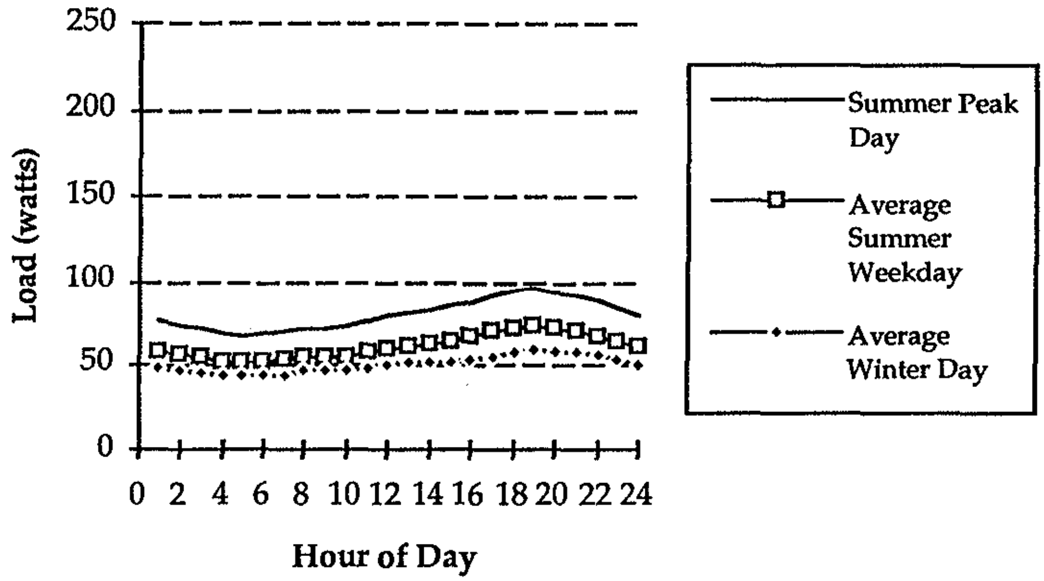


Figure 12. "Rebated" Refrigerator Load Curves

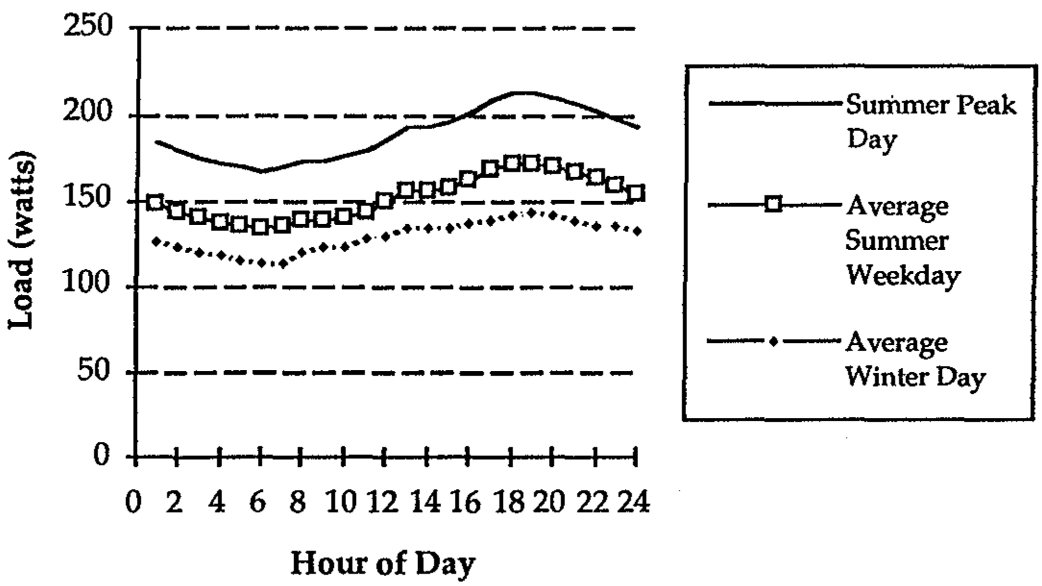


Figure 13. "Typical" Refrigerator Load Curves

APPENDIX D - DETAILED LOAD SHAPE RATIO ESTIMATES

Table 16. Group E Summer Weekday Load Ratios						
Hour	Ratio	SE	CIlow	CIhi	Var	AveW
1	0.9541	0.006	0.943	0.965	3.3E-05	71.0
2	0.9183	0.006	0.906	0.93	3.8E-05	68.3
3	0.892	0.006	0.88	0.904	3.8E-05	66.4
4	0.8582	0.006	0.846	0.87	3.8E-05	63.9
5	0.8419	0.008	0.827	0.857	5.8E-05	62.6
6	0.8524	0.009	0.835	0.87	7.7E-05	63.4
7	0.8727	0.009	0.856	0.89	7.5E-05	64.9
8	0.8931	0.007	0.878	0.908	5.6E-05	66.4
9	0.8881	0.006	0.876	0.9	3.5E-05	66.1
10	0.9101	0.007	0.897	0.923	4.5E-05	67.7
11	0.9442	0.01	0.925	0.963	9.6E-05	70.3
12	0.9819	0.009	0.965	0.999	7.4E-05	73.1
13	1.0069	0.007	0.993	1.02	4.7E-05	74.9
14	1.0292	0.007	1.016	1.043	4.8E-05	76.6
15	1.06	0.007	1.046	1.074	4.8E-05	78.9
16	1.0945	0.009	1.078	1.111	7.3E-05	81.4
17	1.1459	0.01	1.127	1.165	9.4E-05	85.3
18	1.184	0.01	1.165	1.203	9.6E-05	88.1
19	1.195	0.009	1.177	1.213	8.9E-05	88.9
20	1.1724	0.01	1.153	1.192	9.6E-05	87.2
21	1.1461	0.009	1.128	1.164	8.4E-05	85.3
22	1.1083	0.009	1.091	1.126	8.1E-05	82.5
23	1.0584	0.009	1.041	1.076	8.2E-05	78.8
24	0.9926	0.007	0.979	1.006	4.6E-05	73.9

Table 17. Group E Summer Weekend Load Ratios						
Hour	Ratio	SE	CIlow	CIhi	Var	AveW
1	0.9422	0.0065	0.9294	0.9550	4.3E-05	71.4
2	0.9080	0.0069	0.8945	0.9215	4.7E-05	68.8
3	0.8755	0.0066	0.8625	0.8885	4.4E-05	66.4
4	0.8484	0.0064	0.8359	0.8608	4E-05	64.3
5	0.8233	0.0075	0.8086	0.8380	5.6E-05	62.4
6	0.8173	0.0077	0.8021	0.8324	6E-05	62.0
7	0.8195	0.0072	0.8055	0.8335	5.1E-05	62.1
8	0.8489	0.0076	0.8340	0.8638	5.8E-05	64.4
9	0.8768	0.0073	0.8625	0.8910	5.3E-05	66.5
10	0.9208	0.0079	0.9053	0.9362	6.2E-05	69.8
11	0.9707	0.0082	0.9547	0.9867	6.7E-05	73.6
12	1.0170	0.0074	1.0026	1.0315	5.4E-05	77.1
13	1.0370	0.0061	1.0251	1.0489	3.7E-05	78.6
14	1.0653	0.0073	1.0509	1.0796	5.3E-05	80.8
15	1.0896	0.0078	1.0743	1.1049	6.1E-05	82.6
16	1.1120	0.0079	1.0965	1.1275	6.2E-05	84.3
17	1.1589	0.0096	1.1401	1.1777	9.2E-05	87.9
18	1.1764	0.0089	1.1589	1.1939	8E-05	89.2
19	1.1847	0.0095	1.1660	1.2033	9E-05	89.8
20	1.1725	0.0093	1.1543	1.1907	8.6E-05	88.9
21	1.1531	0.0096	1.1342	1.1719	9.2E-05	87.4
22	1.1129	0.0094	1.0944	1.1313	8.8E-05	84.4
23	1.0617	0.0086	1.0449	1.0785	7.3E-05	80.5
24	1.0079	0.0078	0.9927	1.0231	6E-05	76.4

Table 18. Group E Winter Load Ratios for Low Temperatures

Hour	Ratio	SE	CIlow	CIhi	Var	AveW
1	0.9561	0.0058	0.9448	0.9674	3.3E-05	58.6
2	0.9241	0.0062	0.9120	0.9363	3.8E-05	56.7
3	0.8962	0.0062	0.8841	0.9083	3.8E-05	55.0
4	0.8756	0.0064	0.8632	0.8881	4E-05	53.7
5	0.8589	0.0069	0.8454	0.8724	4.7E-05	52.7
6	0.8559	0.0068	0.8425	0.8693	4.7E-05	52.5
7	0.8825	0.0074	0.8679	0.8970	5.5E-05	54.1
8	0.9225	0.0083	0.9062	0.9389	6.9E-05	56.6
9	0.9366	0.0080	0.9210	0.9523	6.4E-05	57.4
10	0.9461	0.0067	0.9330	0.9591	4.4E-05	58.0
11	0.9608	0.0059	0.9494	0.9723	3.4E-05	58.9
12	0.9938	0.0075	0.9791	1.0085	5.6E-05	60.9
13	1.0321	0.0078	1.0168	1.0474	6.1E-05	63.3
14	1.0263	0.0062	1.0142	1.0384	3.8E-05	62.9
15	1.0280	0.0058	1.0166	1.0394	3.4E-05	63.0
16	1.0535	0.0061	1.0416	1.0655	3.7E-05	64.6
17	1.0894	0.0091	1.0716	1.1072	8.2E-05	66.8
18	1.1322	0.0098	1.1130	1.1514	9.6E-05	69.4
19	1.1733	0.0094	1.1550	1.1917	8.8E-05	72.0
20	1.1546	0.0092	1.1365	1.1727	8.5E-05	70.8
21	1.1332	0.0078	1.1178	1.1486	6.2E-05	69.5
22	1.1060	0.0068	1.0926	1.1193	4.6E-05	67.8
23	1.0611	0.0072	1.0471	1.0752	5.1E-05	65.1
24	1.0010	0.0064	0.9885	1.0135	4.1E-05	61.4

Table 19. Group E Winter Load Ratios for Warm Temperatures

Hour	Ratio	SE	CIlow	CIhi	Var	AveW
1	0.9351	0.0065	0.9223	0.9479	4.3E-05	64.4
2	0.9087	0.0064	0.8962	0.9211	4E-05	62.6
3	0.8858	0.0075	0.8711	0.9005	5.6E-05	61.0
4	0.8753	0.0075	0.8606	0.8900	5.6E-05	60.3
5	0.8588	0.0077	0.8436	0.8739	6E-05	59.2
6	0.8553	0.0079	0.8398	0.8708	6.2E-05	58.9
7	0.8790	0.0073	0.8647	0.8933	5.3E-05	60.6
8	0.9069	0.0082	0.8909	0.9230	6.7E-05	62.5
9	0.9084	0.0076	0.8935	0.9232	5.7E-05	62.6
10	0.9176	0.0067	0.9043	0.9308	4.5E-05	63.2
11	0.9480	0.0076	0.9331	0.9629	5.8E-05	65.3
12	0.9794	0.0077	0.9643	0.9945	5.9E-05	67.5
13	1.0080	0.0080	0.9922	1.0237	6.4E-05	69.4
14	1.0137	0.0078	0.9984	1.0290	6.1E-05	69.8
15	1.0486	0.0076	1.0337	1.0635	5.8E-05	72.3
16	1.0855	0.0085	1.0688	1.1022	7.3E-05	74.8
17	1.1341	0.0105	1.1134	1.1547	0.00011	78.1
18	1.1814	0.0106	1.1605	1.2022	0.00011	81.4
19	1.1984	0.0099	1.1791	1.2177	9.7E-05	82.6
20	1.1859	0.0103	1.1657	1.2062	0.00011	81.7
21	1.1413	0.0100	1.1217	1.1610	0.0001	78.6
22	1.0916	0.0090	1.0740	1.1092	8.1E-05	75.2
23	1.0575	0.0083	1.0413	1.0737	6.8E-05	72.9
24	0.9958	0.0067	0.9827	1.0089	4.5E-05	68.6

Table 20. Group T Summer Weekday Load Ratios						
Hour	Ratio	SE	CIlow	CIhi	Var	AveW
1	0.975	0.011	0.953	0.997	0.00013	147.8
2	0.9486	0.011	0.927	0.971	0.00013	143.8
3	0.9276	0.015	0.899	0.956	0.00021	140.6
4	0.9074	0.013	0.881	0.934	0.00018	137.6
5	0.8986	0.017	0.866	0.931	0.00027	136.3
6	0.8803	0.015	0.852	0.909	0.00021	133.5
7	0.8972	0.015	0.867	0.927	0.00023	136.0
8	0.9161	0.014	0.888	0.944	0.0002	138.9
9	0.919	0.012	0.896	0.942	0.00014	139.3
10	0.9303	0.012	0.908	0.953	0.00014	141.1
11	0.9481	0.01	0.928	0.968	0.00011	143.8
12	0.9832	0.014	0.955	1.011	0.00021	149.1
13	1.0226	0.017	0.989	1.056	0.00029	155.0
14	1.0246	0.015	0.995	1.054	0.00023	155.3
15	1.0375	0.018	1.002	1.073	0.00032	157.3
16	1.0645	0.017	1.031	1.097	0.00028	161.4
17	1.1062	0.019	1.069	1.143	0.00036	167.7
18	1.1266	0.017	1.094	1.159	0.00028	170.8
19	1.1322	0.015	1.103	1.162	0.00023	171.7
20	1.1177	0.016	1.086	1.149	0.00026	169.5
21	1.0945	0.015	1.065	1.124	0.00023	166.0
22	1.075	0.013	1.05	1.1	0.00017	163.0
23	1.0466	0.012	1.024	1.07	0.00014	158.7
24	1.0204	0.013	0.995	1.046	0.00017	154.7

Table 21. Group T Summer Weekend Load Ratios						
Hour	Ratio	SE	CIlow	CIhi	Var	AveW
1	0.9829	0.012	0.96	1.006	0.00014	150.0
2	0.9414	0.011	0.92	0.963	0.00012	143.7
3	0.9281	0.015	0.9	0.957	0.00021	141.6
4	0.914	0.015	0.885	0.943	0.00022	139.5
5	0.8985	0.017	0.866	0.931	0.00028	137.1
6	0.8695	0.014	0.842	0.897	0.0002	132.7
7	0.8685	0.015	0.838	0.899	0.00024	132.5
8	0.8886	0.013	0.863	0.915	0.00018	135.6
9	0.9181	0.013	0.893	0.943	0.00016	140.1
10	0.9383	0.013	0.913	0.963	0.00016	143.2
11	0.9608	0.011	0.94	0.982	0.00012	146.6
12	0.995	0.013	0.97	1.02	0.00016	151.8
13	1.0323	0.015	1.002	1.063	0.00024	157.5
14	1.0415	0.015	1.013	1.07	0.00022	158.9
15	1.0531	0.016	1.021	1.085	0.00026	160.7
16	1.0911	0.016	1.059	1.123	0.00027	166.5
17	1.1102	0.017	1.077	1.144	0.00029	169.4
18	1.1102	0.017	1.078	1.143	0.00027	169.4
19	1.129	0.015	1.1	1.158	0.00021	172.3
20	1.1182	0.013	1.093	1.143	0.00016	170.6
21	1.0954	0.014	1.068	1.122	0.00019	167.2
22	1.0705	0.012	1.047	1.094	0.00014	163.4
23	1.0352	0.01	1.015	1.055	0.0001	158.0
24	1.0094	0.015	0.98	1.039	0.00022	154.0

Table 22. Group T Winter Load Ratios for Low Temperatures						
Hour	Ratio	SE	CIlow	CIhi	Var	AveW
1	0.9756	0.01	0.956	0.995	9.6E-05	125.3
2	0.956	0.018	0.92	0.992	0.00034	122.8
3	0.9297	0.011	0.909	0.951	0.00011	119.4
4	0.9157	0.017	0.883	0.949	0.00028	117.6
5	0.8947	0.013	0.868	0.921	0.00018	114.9
6	0.8827	0.01	0.862	0.903	0.00011	113.4
7	0.8831	0.011	0.862	0.904	0.00011	113.4
8	0.9287	0.01	0.909	0.949	0.0001	119.3
9	0.949	0.011	0.927	0.971	0.00013	121.9
10	0.9503	0.01	0.931	0.97	9.8E-05	122.1
11	0.9904	0.015	0.961	1.02	0.00023	127.2
12	1.0022	0.014	0.976	1.029	0.00018	128.7
13	1.0348	0.013	1.01	1.06	0.00016	132.9
14	1.0408	0.016	1.009	1.073	0.00026	133.7
15	1.0404	0.013	1.014	1.066	0.00018	133.6
16	1.0626	0.017	1.03	1.096	0.00028	136.5
17	1.0759	0.012	1.052	1.1	0.00015	138.2
18	1.0998	0.013	1.074	1.126	0.00018	141.3
19	1.1086	0.014	1.081	1.136	0.0002	142.4
20	1.0979	0.013	1.073	1.123	0.00016	141.0
21	1.07	0.012	1.047	1.093	0.00013	137.4
22	1.0446	0.011	1.022	1.067	0.00013	134.2
23	1.0438	0.015	1.014	1.073	0.00023	134.1
24	1.0228	0.013	0.998	1.048	0.00017	131.4

Table 23. Group T Winter Load Ratios for Warm Temperatures						
Hour	Ratio	SE	CIlow	CIhi	Var	AveW
1	0.9736	0.013	0.949	0.998	0.00016	140.1
2	0.9447	0.012	0.922	0.968	0.00014	135.9
3	0.9382	0.013	0.913	0.963	0.00016	135.0
4	0.9054	0.014	0.878	0.933	0.0002	130.3
5	0.8958	0.012	0.873	0.919	0.00014	128.9
6	0.8842	0.013	0.86	0.909	0.00016	127.2
7	0.8941	0.01	0.875	0.914	9.8E-05	128.6
8	0.9306	0.011	0.909	0.953	0.00013	133.9
9	0.9295	0.012	0.905	0.954	0.00015	133.7
10	0.9337	0.011	0.911	0.956	0.00013	134.3
11	0.9497	0.012	0.927	0.973	0.00014	136.6
12	0.9896	0.013	0.964	1.015	0.00017	142.4
13	1.0154	0.016	0.983	1.048	0.00027	146.1
14	1.0084	0.012	0.985	1.032	0.00014	145.1
15	1.0327	0.015	1.002	1.063	0.00024	148.6
16	1.0481	0.013	1.022	1.074	0.00017	150.8
17	1.0973	0.015	1.068	1.127	0.00022	157.9
18	1.1214	0.015	1.092	1.151	0.00023	161.3
19	1.1368	0.016	1.105	1.168	0.00026	163.5
20	1.1308	0.015	1.101	1.161	0.00023	162.7
21	1.1002	0.014	1.072	1.128	0.0002	158.3
22	1.0597	0.011	1.038	1.082	0.00013	152.5
23	1.048	0.01	1.028	1.068	0.00011	150.8
24	1.0319	0.013	1.005	1.058	0.00018	148.5

APPENDIX E - TEMPERATURE BINS

Table 24. Temperature Bins - PG&E Residential Customers.				
Bin	November 1 - April 31		May 1 - October 31	
	Days	Weighted Mean Temperature (°F)	Days	Weighted Mean Temperature (°F)
>25<=30°F	0.022	28.9	0.000	NA
>30<=35°F	0.363	32.9	0.000	NA
>35<=40°F	3.033	38.8	0.000	NA
>40<=45°F	16.540	43.9	0.055	44.3
>45<=50°F	41.175	48.0	0.282	49.6
>50<=55°F	66.589	52.6	1.832	53.9
>55<=60°F	43.800	57.0	32.813	58.2
>60<=65°F	7.697	61.7	69.728	62.8
>65<=70°F	1.490	66.2	40.275	67.3
>70<=75°F	0.291	71.3	18.389	72.5
>75<=80°F	0.000	NA	11.448	77.3
>80<=85°F	0.000	NA	6.907	81.6
>85<=90°F	0.000	NA	2.185	87.0
>90<=95°F	0.000	NA	0.085	90.3

APPENDIX F - VARIABLES LIST	
Variable code	Description
Avg temp	average daily outside temperature, °F nearest weather station
Kit temp	kitchen temperature measured at technician visits, °F
Icemaker	if on (=1), if not (=0)
Sweat	anti-sweat heater switch setting: on (=1), off (=0)
Occupants	number of people in household[1]
House Size	floor area of home, sq. ft.[1]
Frez temp	freezer temperature measured at technician visits,°F
Frez set	freezer setting, between coldest (=100) & warmest (=0)
Ref temp	fresh food temperature measured at technician visits,°F
Ref set	thermostat setting, between coldest (=100) & warmest (=0)
Lab kWh	label consumption data, kWh/yr
Fresh vol	volume of fresh food space, cu.ft.
Frez vol	volume of freezer space, cu.ft.
Adjusted vol	1.63 x Frez vol + Fresh vol, cu.ft.
Coil location	location of condenser coil, back (=1), bottom (=0)
Evap cooler	does house have an evaporative cooler? yes (=1), no (=0)
Evap time	normal operation time for evaporative cooler, hour of day[1]
AC	does house have an air conditioner? yes (=1), no (=0)
AC time	normal operation time for AC, hour of day[1]
T-stat day	summer daytime house thermostat setting, °F[1]
T-stat night	summer nighttime house thermostat setting, °F[1]
Clear (1 to 6)	Six different clearances between refrigerator and walls, etc., inches
Seal	condition of door seal, good (=1), bad (=0)
LO load	frequency of leftover loading, occurrences per day[1]
LO temp	temperature of leftover loading, hot (= 1), cool (=0)[1]
Ht source	is refrigerator near a heat source? yes (=1), no (=0)[1] (also which one)
Door open	number of door openings midnight to 6 AM[1]

1 Reported by occupant.