92.101

Prepared by:
Proctor Engineering Group, Ltd.
San Rafael, CA 94901
(415) 451-2480

Targeted DSM to Delay T &D Expenditures at the Paradise Substation

Prepared for:
Pacific Gas and Electric Company
Energy Efficiency Services Department

Final Report
July 12, 1993

Contributors:
George Peterson, P .E.
John Proctor, P .E.

Creators of CheckMe!®

Table of Contents

List of Tables

List of Figures

Executive Summary

The area serviced by the Paradise Substation is a mostly residential area with Substation load growing about 2.4% per year. The Paradise Substation currently has a capacity of 61,300 kW. Paradise Substation's all time highest demand (53,100 kW) occurred at 5:30 PM, Monday August 6, 1990. The potential maximum peak load on the Substation (based on weather that is expected only once every twenty years) could exceed that capacity in 1995. The purpose of this study was to determine the feasibility of implementing a targeted T&D DSM project which could successfully delay the need for increased capacity. In 1995 the projected capacity shortfall is 186 kW. Each year thereafter the load is projected to increase by about 1.38 MW. Due to a slower growth rate and other considerations the 1995 potential shortfall may be considered an insignificant risk.

This study focused on the most important end use contributors to the Paradise peak demand. Five end uses (residential central air conditioning, residential evaporative coolers, residential refrigerators, small commercial air conditioners, and residential freezers) constitute 72% of the local area peak. Residential central air conditioning alone accounts for over 40% of local area peak.

Major contributors to local peak were identified using peak data from various PG&E studies (including AMP) and saturations from RASS . The results were tuned to the actual peak recorded for the Paradise Substation. Measures worthy of detailed analysis were selected based on:

- Maturity of the technology
- Confidence in the peak load reduction
- Likelihood of customer acceptance
- Potential for significant load reduction

This methodology identified seven combinations to be evaluated in depth. These combinations of technologies were evaluated for potential peak reduction, potential market penetration, and cost effectiveness. The critical interactions between residential AC sizing, ambient temperature, and occupant behavior were analyzed with a new residential AC model. The results of that analysis are displayed in Table A.

Table A Savings Potential, Required Market Penetration, and Benefit/Cost Ratio

DSM Program	Total Peak Reduction (kW)	Market Penetration	Benefit/Cost Ratio (TRC)
Res. Central AC Downsized Replacement with Heat Gain Reduction	1,552	25%	0.77
Res. Window AC Replacement	262	35%	1.96
Res. Refrigerator Replacement	336	25%	0.92
Res New Construction	996	50%	1.78
Comm. Special Projects	200	N.A.	1.0
Small Commercial	268	15%	1.14
Cool Room DC	2,847	25%	1.14

There is sufficient DSM potential in the load on the Paradise Substation to delay capacity addition for three to five years, however, the comprehensive effort needed to achieve this level of load reduction is not cost effective at this time. The study details a five year delay based on a $5.2 million DSM project achieving 6,462 kW of load reduction. The approach developed in this study would be applicable to other areas.

Implementation would have to begin in the summer of 1993. PG&E is under regulatory constraint to not begin any DSM for T&D benefits until the Model Energy Communities (MEC) program evaluation is complete. The final MEC evaluation is not expected within the time frame necessary for the Paradise Substation expansion.

Due to cost effectiveness, regulatory, and timing issues we recommend that PG&E not proceed with a targeted T&D DSM project for Paradise at this time.

The overall methodology of this analysis could be integrated into a format easily usable by PG&E for future screening of potential T&D DSM projects. Development of that package would reduce the time and cost associated with such a screening.

We recommend that the analysis methodology be further refined by additional data on AC customers, homes, and loads.

The AC model used in this analysis provides increased clarity and confidence in projections of residential AC peak reductions.

I. Background and Baseline Data

A. TARGETED DSM GOALS AND TIMELINES

The area serviced by the Paradise Substation is a mostly residential area with Substation load growing about 2.4% per year. The Paradise Substation currently has a capacity of 61,300 kW. The potential maximum peak load on the Substation (based on weather that is expected only once every twenty years) could exceed that capacity in 1995. The purpose of this study was to determine the feasibility of implementing a targeted T&D DSM project which could successfully delay the need for increased capacity. In 1995 the projected capacity shortfall is 186 kW. Each year thereafter the load is projected to increase by about 1.38 MW. Paradise Substation's all time highest demand (53,100 kW) occurred at 5:30 PM, Monday August 6, 1990.

In order to be viable, the targeted DSM must reliably hold the maximum peak below the Substation capacity. Any shortfall in DSM capacity could have consequences that outweigh the potential benefits. There needs to be a reasonable and prudent safety factor. Adequate advance notice must be provided for the Substation expansion to be built in a timely manner. It is assumed that DSM resources must be firm and provable three years before they are needed. This is based on the following analysis.

Two components of the local area peak are considered, connected load and extreme weather conditions. Under normal weather conditions the peak increases each year based on connected load growth. Occasionally there is extremely hot weather causing a high peak. The weather conditions which cause a local area peak demand occur very infrequently. Because of hotter weather the actual peak demand of the Paradise Substation in 1990 was higher than 1991 or 1992 even though the connected load had grown substantially each year. The maximum potential demand must be predicted and planned for even though an actual test of that prediction will, on average, occur only once in twenty years (95% Weather Peak). Figure 1 illustrates the summer 1990 weather in Chico, CA, the closest weather station to Paradise.

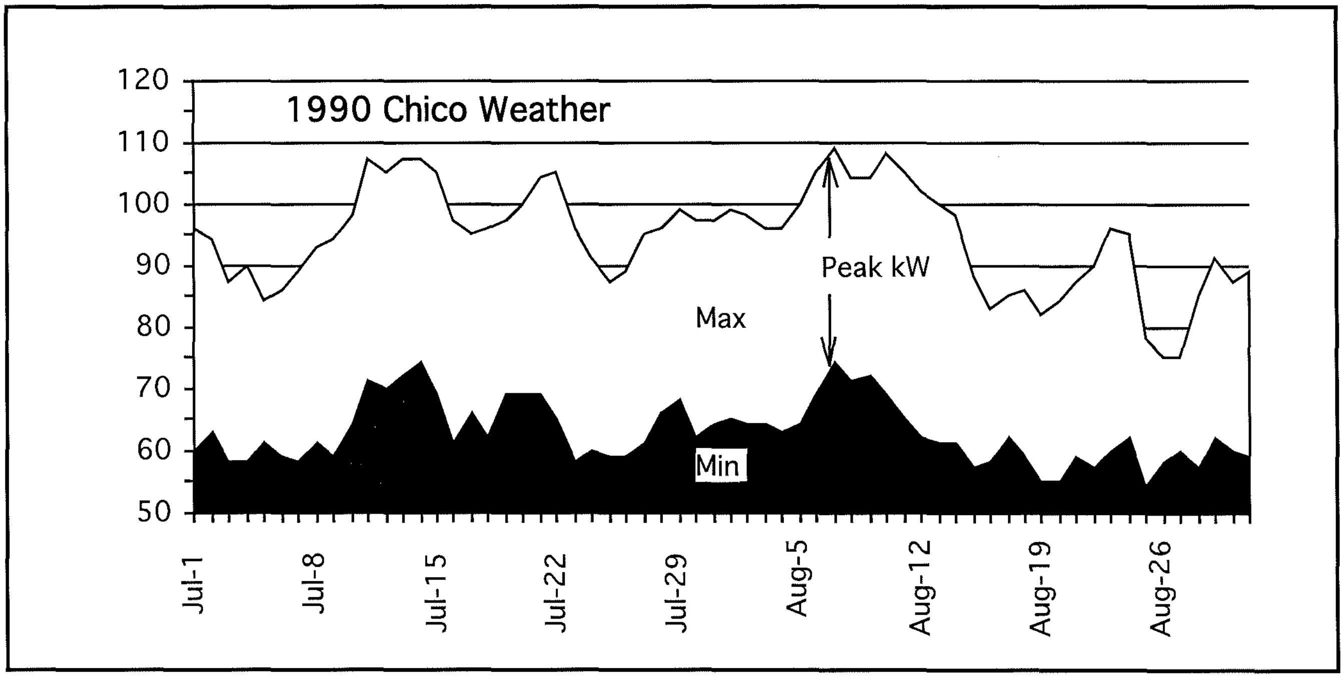

Figure 1 Summer Weather in Chico CA (Near Paradise)

The peak load is not just determined by the daily maximum temperature. The peak occurs on August 6, when the daily maximum is 105°F, not August 7 with a 109°F maximum. The other important factor is the minimum temperature. The high usage occurs when it doesn't cool down in the late afternoon.

Work has been completed by AUS which projects the peak use for the Paradise Substation under different scenarios. Figure 2 presents that data. The maximum demand occurred in 1990, followed closely by 52,900 kW in 1991. When the historical maximum peak trend is projected to future years, the Substation is projected to be under capacity in 1996. When the data is normalized based on weather and projected based on the 95% weather condition, the capacity is exceeded by 186 kW in 1995.

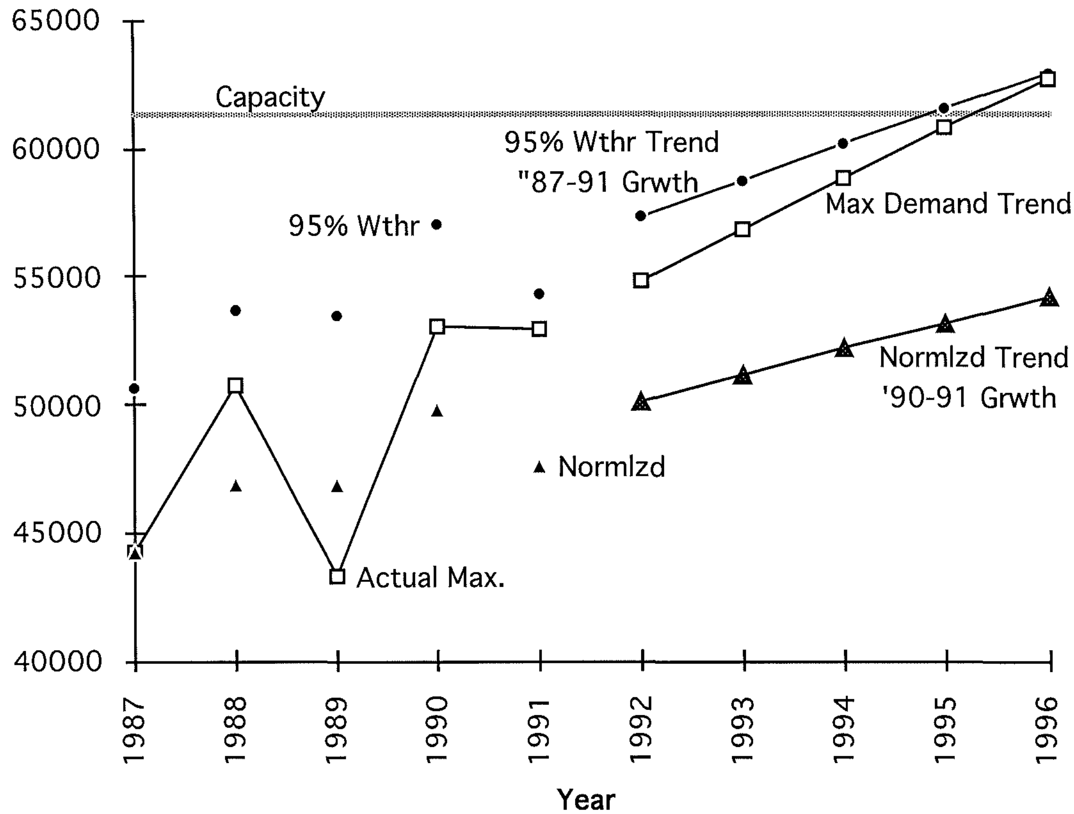

Figure 2 - AUS Projected Load for Paradise Substation

The timing of the capacity increase at the Paradise Substation is critical. The peak demand usually occurs in July or August, but abnormally hot weather might cause an earlier peak. To allow for abnormally early hot weather the Substation expansion should be in place by June. According to Donovan Currey of the Paradise District Office, it usually takes 1 $^{1}/_{2}$-2 years to purchase and install the necessary equipment for the Substation expansion. A final decision to expand would be needed in June two years prior. An analysis of the effectiveness of the targeted DSM project upon peak reduction should be completed by May. This analysis would study the actual local area peak which occurs during the latest year's hottest summer weather (July or August of the third year prior to anticipated need). The measures would need to be in place before the hot weather in May. This timeline assures that capacity addition will occur in a timely manner and that any delay of construction based on targeted DSM for T&D is based on proven reductions in maximum potential demand. Since DSM is not considered a certain capacity resource until it is in place and verified, it must proceed on a sequential rather than parallel track to the capitol improvement. The necessary schedule is shown in Table B.

Table B Timeline for Targeted DSM to Delay Capacity Addition

Task or Step				
Prepare for Peak in:	July 1995	July 1996	July 1997	July 19xx
Build Substation by	June 1995	June 1996	June 1997	June 19xx
Final decision to build	June 1993	June 1994	June 1995	June 19xx-2
Proof of peak load reduction	May 1993	May 1994	May 1995	May 19xx-2
Actual peak reduction	July or Aug. 1992	July or Aug. 1993	July or Aug. 1994	July or Aug. 19xx-3
DSM installed by	June 1992	June 1993	June 1994	June 19xx-3

This schedule cannot be realized for the 1995 potential capacity shortfall at the Paradise Substation. However, the projected shortfall is only 186 kW which may be viewed as a slim risk given the slowed growth and safety margins in the design.

B. LOAD CHARACTERISTICS

The majority of DSM attention has been focused on the problem of the system peak. The Paradise Substation and many other local planning areas experience a local area peak driven by residential end users. The local peak of a predominantly residential area differs in important ways from the system peak. The primary differences are:

- The residential peak occurs later, usually 5:00-6:00 PM as residents return home and turn on air-conditioners.
- The residential peak is sharper and has a shorter duration.
- While the residential peak has no large controllable loads, it has a larger component of discretionary usage.
- The air-conditioning load causing the residential peak is dominated by external gains. The internal gain is much smaller than in commercial (the lighting load is small).

Figure 3 shows the Paradise Substation and PG&E system load shapes for August 6, 1990, the historical highest load for the Paradise Substation.

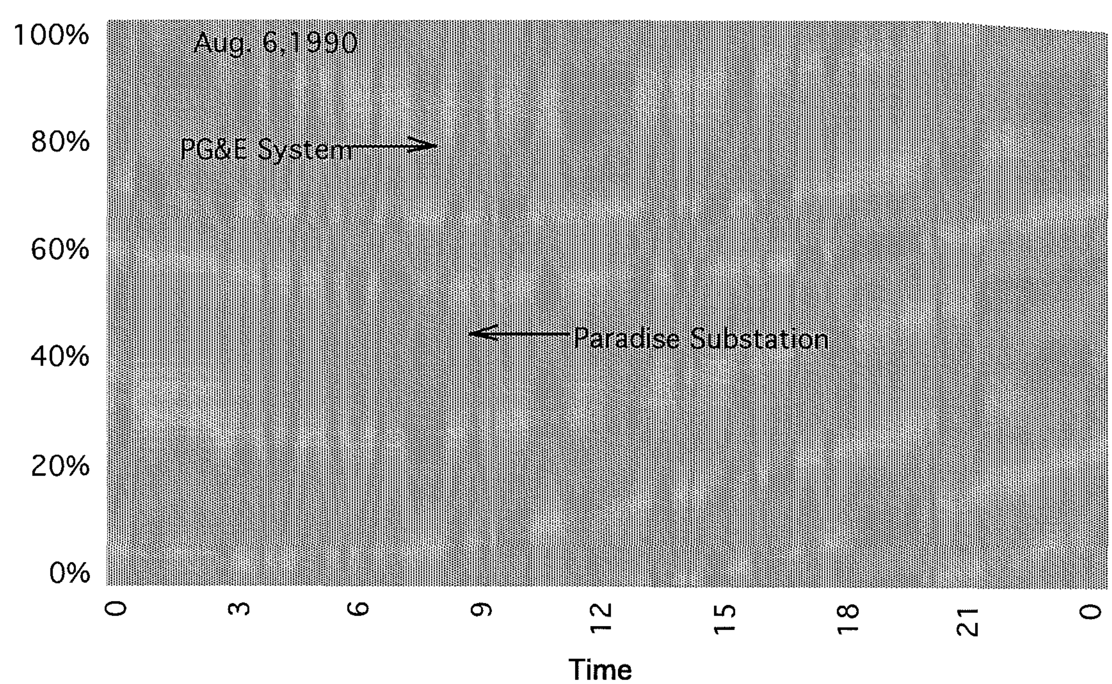

Figure 3 Local Area Peak Load Shape

This study focused on the most important end use contributors to the Paradise peak demand. The aggregate use estimates were calculated for August 6, 1990. The peak use estimate for each end use was calculated as shown in Appendix B. The aggregation of these estimates was compared against the historical data and the model adjusted.

It is clear from Figure 4 that residential central air conditioning is the largest contributing end use to the local peak. In order to significantly reduce the peak demand, this end use must be addressed.

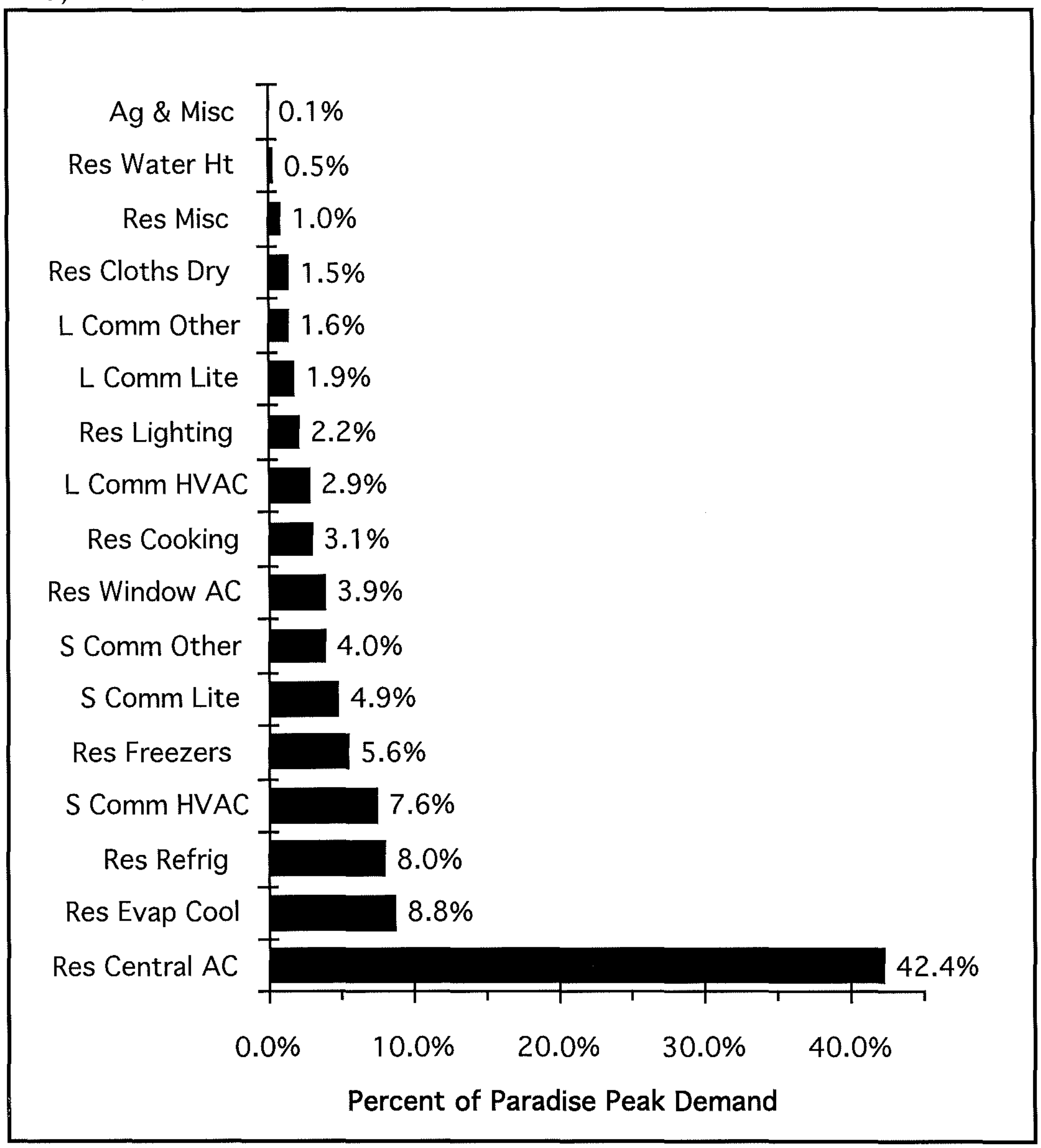

Figure 4 Composition of Peak Demand by End Use

The calculated scenario addresses three of the top four end uses; residential central air conditioning, residential refrigerators, and small commercial air conditioning.

C. MODEL OF PARADISE SUBSTATION DELAY

Some of the important factors that were considered in modeling the Substation construction delay decision include:

- Cost effectiveness of potential DSM projects.
- Appropriateness of targeted DSM for T&D benefits to the Paradise Substation.
- Special circumstances of capacity addition at the Paradise Substation
- Reliability and technical considerations
- Regulatory issues

Cost of Capacity Addition

The cost of the capacity addition to the Paradise Substation is estimated as \$1,200,000 ±20%. Assuming 11% [1] as the time value of money, the value of delayed construction is \$132,000/year. This translates into \$710/kW for the first year of delay and \$96/kW for subsequent years. The calculation of total resource benefits does not yet take into account the timing of specific T&D projects.

Short Term Appropriateness

The benefit of delay is equal to the time value of the construction costs. All else being equal, the longer a particular program expenditure and load reduction delay construction, the greater the benefit. Therefore, targeted DSM for T&D benefits may be most appropriate for slow growing areas, when only a single construction project is considered. In a longer term analysis, fast growth areas may be more appropriate.

Special Circumstances

Through fortuitous circumstances the Paradise Substation was able to obtain used PG&E equipment that represents 30% of the necessary costs of capacity addition. Thus the estimated future expenditure for expansion is \$700,000 ±20%, or \$320/kW for the first year of delay and \$43/kW for subsequent years.

Reliability and Technical Considerations

Approximately two years are needed from the time of the final decision to build until the added capacity is in place. To ensure an adequate safety factor, DSM

---

[1]PG&E discount rate supplied by General Office

load reductions must be highly reliable and proven three years prior to the capacity need. To delay a 1995 capacity addition, DSM load reduction should have been demonstrated in the summer of 1992.

The peak reduction measures with very low costs per kW are either not fully tested or do not have sufficient potential total kW reduction benefits. Given the short time frame and area growth, the implemented measures would need to provide high levels of reliable reduction.

Regulatory Issues

The current regulatory status of DSM for T&D benefits is that no new projects are to be begun by PG&E until the Model Energy Communities (MEC) program evaluation is complete. The final MEC evaluation is not expected within the time frame necessary for the Paradise Substation expansion.

II. Peak Reduction Strategy Screening

The goal of the screening is to focus on strategies that can reasonably be expected to contribute to the delay of the Paradise Substation upgrade. Strategies that pass this screening warrant detailed analysis.

A. CRITERIA FOR SELECTION

Measures selected for detailed analysis meet these criteria:

- Mature technology
- Peak load reduction
- Customer acceptance
- Sufficient load reduction potential

Other measures appear to have significant load reduction potential but the reliability of that potential isn't sufficiently proven and/or the technology has not yet been proven durable and mature.

Mature Technology

The technology must: be commonly manufactured, have a viable delivery infrastructure in place, and been in the market long enough for initial problems to surface (usually about 3 years). It must be known to be reliable, durable, and free of problems.

Peak Load Reduction

The technology should have been field tested in a similar climate. For a major project commitment with large expenditures, engineering estimates are a poor substitute. Nevertheless, most of the "peak reduction technologies" have not been verified and we must rely on theoretical calculations.

Customer Acceptance

For this project, high penetration will be necessary. This requires some assurance that customers will accept the measure.

Sufficient Load Reduction Potential

The potential load reduction in the targeted area must be large enough to justify the additional administrative expense. Many technologies, while mature and proven, can not provide enough load reduction to justify the administrative overhead of an implementation project.

B. SELECTION MATRIX

Italicized measures have been selected for detailed analysis.
(P) are measures suggested for pilot testing.

Measure	Mature technology	Peak reduction	Customer acceptance	Sufficient load reduction potential
Residential Central AC				
Downsized Replacement	Yes	Theoretical	Yes	In Combination Only
High Efficiency Replacement	Yes	Yes	Yes	In Combination
Distribution System Repair	Borderline	Theoretical in Combination	Yes	In Combination Only
Distribution System Insulation	Borderline	Theoretical in Combination (P)	Unknown (P)	In Combination Only
AC Tune Up	No	Overcharge Only	Yes	No
Evaporative Cooling	Yes	Yes	Unknown (P)	Yes
Attic Insulation	Yes	Theoretical	Yes	In Combination Only
Wall Insulation	Yes	Theoretical	Borderline	In Combination Only
Attic Venting	Yes	Yes(P)	Yes	No
Infiltration Reduction	Borderline	Theoretical	Unknown	Unknown
Roof/Wall Shading (Trees, etc.)	Yes	Theoretical	Yes	No

Measure	**Mature technology**	**Peak reduction**	**Customer acceptance**	**Sufficient load reduction potential**
Roof/Wall Coatings	No	Some Empirical Data (P)	Unknown (P)	Unknown(P)
Condensing Unit Shading	No	Theoretical	Yes	No
Condensing Unit Relocation	Yes	Theoretical	No	No
Window Shading	Borderline	Yes	Borderline	No
Window Films	Borderline	Yes	Borderline	No
Selective Glazing	Yes	Yes	Yes in New Construction	Yes in New Construction
"Cool Room" Concept	A Combination of Mature Technologies	Theoretical (P)	Unknown (P)	Yes
Lock Out /Switching	Yes	Yes	Yes	No
Ground Source	Borderline	Yes	Unknown (P)	In New Construction
Residential Window AC				
High Efficiency Replacement	Yes	Yes	Yes	Yes
Downsized Replacement	Yes	Theoretical	Unknown	No
AC Tune Up	No	Overcharge Only	Yes	No
Evaporative Cooling	Yes	Yes	Unknown	No
Lock Out/Switching	Yes	No	No	No
Residential Electric Water Heating				
Lock Out/Switching	Yes	No	Yes	No
Heat Pump Water Heater	Yes	Yes	No	No
Flow Controls	Yes	Yes	Yes	No
Insulation	Yes	Yes	Yes	No

Measure	Mature technology	Peak reduction	Customer acceptance	Sufficient load reduction potential
Residential Lighting				
Compact Fluorescent Lamps	Yes	Yes	Yes	No
Fluorescent Replacement Fixtures	Yes	Yes	Yes	No
Residential Cloths Drying				
Replacement	Yes	Yes	Yes	No
Lock Out/Switching	Yes	Yes	Unknown	No
Residential Refrigeration				
High Efficiency Replacement	Yes	Yes	Yes	Yes
Tune Up	Yes	No	Unknown	No
Single larger unit replaces second refrigerator	Yes	Yes	Unknown (P)	Yes
High Efficiency Replacement Freezer	Yes	Unknown (P)	Yes	Unknown (P)
Residential Cooking	Yes	Yes	Yes	No
Other Residential				No
Large Commercial Projects	Yes	Yes	Yes	Yes
Small Commercial				
Window Films	Yes	Yes	Yes	Yes
AC Replacement	Yes	Yes	No	Yes

C. MEASURES SELECTED FOR DETAILED ANALYSIS

The strategies selected as primary are:

- Residential central AC downsized high efficiency replacement combined with cooling load reduction
- Early replacement of residential window air-conditioners
- Early replacement of residential refrigerators
- Load reduction in new construction
- Individualized commercial projects for larger customers
- Window films for small commercial customers
- "Cool Room" load control

A complete summary of these measures is included in Appendix B

Measure #1 - Residential Central AC (Downsized High Efficiency Replacement Combined with Cooling Load Reduction)

The primary strategy is the replacement of existing central air conditioners with properly sized high efficiency units after available cost effective heat gain reduction techniques have been applied. This strategy includes the following features: downsizing, high efficiency at high temperatures, shell improvements and distribution system improvements.

DOWNSIZING
Downsizing an air conditioner (with no other changes) reduces the electrical load when the unit is running continuously. Downsizing oversized AC units can result in significant load reduction.

Oversizing can occur because the original equipment capacity exceeds the design cooling load for the building. Experience in the Model Energy Communities (MEC) project showed that, on average, air-conditioners were initially oversized by 0.25 ton. However, if undersized units are eliminated, average oversizing equals approximately 0.6 ton.

Additional shell and distribution measures can be implemented which reduce the effective load and make the unit even further oversized. Nevertheless, in a significant number of cases, the implementation of shell and distribution measures by themselves will not appreciably affect peak demand. In cases where the occupant returns to a warm house and turns on the AC it will run continuously for a cool down period. This cool down period may extend throughout the time of area peak load. For these units the peak benefits from shell and distribution improvement can occur only when combined with downsizing.

Downsizing should be combined with high efficiency replacement. It also provides a number of other advantages including lower replacement costs (approx. $280 less per ton from MEC bids) and improved cfm/ton air flow through the inside coil.

HIGH EFFICIENCY AT HIGH TEMPERATURE
Replacing an air conditioner with a high efficiency @ high temperature unit reduces the electrical load whenever the unit is running.

High efficiency at high temperature is not the same as high SEER (or even high EER at 95°F). SEER is an efficiency based primarily on a test at 82°F ambient. As the ambient temperature increases the efficiency decreases. As a result the efficiency (EER) at rated conditions (95°F) is less than the EER at 85°F. The Paradise area peak occurs at an ambient temperature of about 105°F (based on Chico median annual maximum of 109°F, lower temperature at Paradise, and local peak occurring after ambient temperature drops off maximum). Different pieces of equipment have very different relationships between efficiency and temperature. Therefore an air conditioner with a high SEER may be less efficient at 105°F than a unit with a somewhat lower SEER. To achieve maximum peak reduction benefit, equipment should be chosen on the basis of operating efficiency at the expected peak conditions.

COOLING LOAD REDUCTION BY SHELL MEASURES
Reducing the cooling load can reduce the diversified electrical load for air conditioners that can cycle at peak. The cooling load can be reduced by increasing the thermal integrity of the building shell. The primary strategies are:

- Attic insulation
- Wall insulation (if only a minor rebate to the customer is necessary)

The effect of these items on peak demand is highly interactive with the occupants control of the air conditioning system (see Section III). These interactions make downsizing a critical element in peak reduction by building shell improvement.

EFFECTIVE COOLING LOAD REDUCTION THROUGH DISTRIBUTION SYSTEM MEASURES
Like building shell measures, distribution system measures can reduce the cooling the air conditioner must supply. Duct insulation and duct leakage repair are primary measures. Duct leakage adds to air conditioning load by loss of conditioned air to outside the thermal envelope, by drawing in hot air from the hot attic, and/or by causing pressure imbalances which increase the infiltration rate and heat gain. Duct leakage has been shown to be a major source of air-

conditioning inefficiency (Proctor 1991). The average amount of available duct sealing in the Model Energy Communities (MEC) project equates to a 0.5 ton of cooling load. This reduction will not necessarily translate into peak reduction unless the air conditioner is downsized to reduce the connected load.

Measure #2 - Early Replacement of Residential Window Air Conditioners

The replacement of existing window air conditioners with high efficiency units is an important measure. AMP data indicates that the diversified load from window air conditioners is 2.263 kW at 5 PM. This is 88% of the same AMP data for central air conditioners[2].

Measure #3 - Early Replacement of Residential Refrigerators

This strategy involves financial incentives to induce the early retirement of refrigerators over 10 years old and replacement with new high efficiency models.

Measure #4 - Load Reduction in New Construction

Increased load from new construction is the major contributor to the increased peak and required capacity addition. In residential new construction the capacity costs are only the incremental costs and not the full cost of retrofit. Many technologies which can not be economically installed as retrofits are cost effective in new construction. If installation at the time of new construction is missed, recapturing this lost opportunity may not be economically feasible.

Many energy and peak reduction strategies are already incorporated within California building codes. However three areas of potential improvement remain: duct sealing, selective glazing on West windows, and smaller high efficiency (at high temperature) AC units.

DUCT SEALING
It is much easier to seal the duct work properly when it is first installed and exposed than to retrofit it later.

SELECTIVE GLAZING ON WEST WINDOWS
The local area peak occurs at 5:00 to 6:00 PM when the sun is beginning to set in the west. Solar gain through the west windows adds about 0.5 ton peak cooling load to an average house. This can be reduced 60% with the use of spectrally selective glazing while maintaining high visible transmittance and color neutrality. The best glazing combines special glass with a matched spectrally

---

[2]PG&E Appliance Metering Project: Window AC Table B-5; Central AC Table B-3 (2.555kW). AMP data is system wide, the Paradise specific central AC demand is estimated as 3.753 kW

selective coating in a dual pane sealed unit. This is only available in new applications or a complete window pane replacement.

SMALLER AIR CONDITIONERS WITH HIGH EFFICIENCY AT HIGH TEMPERATURES

This measure is identical to the same measure in the retrofit category. It is less expensive to accomplish during initial build.

Measure #5 - Individualized Commercial Projects for Larger Customers

While the Paradise area is dominated by the residential load, there are a few larger commercial loads on the system. These include a local hospital, three supermarkets, a community college, a large retail store, a local water district, and other commercial accounts. There are 30 demand billed customers (0.16% of accounts) representing approximately 3334 kW of peak demand (6.4% of demand). The advantage of commercial projects is that a relatively large load reduction is available in one place.

Discussions with local area service representatives have indicated that commercial peak load reduction potential does exist in the Paradise area. However, the decision makers often are not local. It has been suggested that General Office corporate account representatives may be better able to influence decision makers if significant load reduction is sought from this sector.

Measure #6 - Window Films for Small Commercial Customers

There are 1844 non-demand billed non-residential accounts in the Paradise area. These include some agricultural and exterior lighting accounts, but are mostly small retail and small offices. The 1990 combined coincident peak load of this sector is estimated as 8,593 kW or 16.5% of the total.

The predominant peak contributory end uses are air-conditioning and lighting; estimated to represent 7.6% and 4.9% of the local area peak respectively. A small commercial air-conditioner program was considered, however, because the ownership of the unit and the responsibility for utility payments are often different entities (building owners and tenants respectively), high market penetration would be difficult to be achieve. The primary measure is a direct installation program of solar control window film on West facing glazing. Heat gain reduction in small commercial is expected to have a more direct effect on peak reduction than in the residential sector for two reasons:

1. AC sizing: Commercial air conditioners are usually sized larger to accommodate the greater uncertainty of load and changes of use.

2. Thermostat settings: Commercial air conditioners are usually operated at constant thermostat setting which promotes cycling with duty cycles proportional to heat gain.

Window films are a proven technology in the commercial sector. However until recently, the available products tended to be unsightly and impair window displays and views. New products with high visible transmittance and color neutrality overcome these previous drawbacks. The high coincidence with the local area peak of heat gain through West windows helps to make window films the most cost effective of the potential retrofits in the small commercial sector.

Measure #7 - "Cool Room" Load Control

The "Cool Room" is a new concept developed by Proctor Engineering. It is a unique mixture of mature technologies. The "Cool Room" relies on two lifestyle attributes of many people. First, people usually spend particular hours of the day in particular rooms of the house. In a household from 5:00-7:00 PM the majority of activity may be in the living room, kitchen, or family room. If that room is cooled from 5:00 to 7:00 the occupants would receive the majority of the benefits of air conditioning. Second, many people are willing to trade some level of comfort for financial gain. For a reasonable financial incentive these people would accept a reduced level of comfort.

The "Cool Room" offers the greatest potential for peak load reduction at a low cost. Each customer in the cool room program is given a room air-conditioner, installed in the room most frequently occupied 5:00 to 7:00 PM weekdays. During times of capacity constraint, the customer has a comfortable cool room to go, while the customer's central AC is locked out on a signal from PG&E. During the vast majority of the year the occupants would experience no restriction on the air conditioner usage. During the hottest days, the occupants would have the most commonly occupied portion of the residence comfortable. Because the local peak period is sharp and late in the afternoon, the duration of interruptions would be short, no longer than two hours, and after the highest heat of the day. With the use of a small window unit, many customers will notice little decrease in comfort, especially if the house is already cool at the start of the interruption. For the first three years of delay, the direct control is not expected to be needed. The DC acts as a buffer from any unexpected increase of local load or shortfall of DSM load reduction. If the "Cool Room" proves successful during this period, an additional two years of delay may be possible based on direct control.

III. Estimating Residential Air Conditioner Peak Load Reduction Potential

Because over 40% of the local peak is due to residential central air conditioning substantial resources must be focused on that end use. The most detailed analysis of this study was directed at residential central air conditioning. Proctor Engineering Group has developed an innovative model to improve the predictions of peak reduction from central AC measures. This model accounts for customer behavior, design and installation effects that are lost in simpler linear models.

There are several central air conditioner measures that were analyzed, these include:

- High Efficiency AC Units
- AC Downsizing
- AC Repairs
- Building Shell Measures
- Distribution System Measures

A. RESIDENTIAL AIR-CONDITIONER OPERATION

In order to predict the effect of various technologies designed to reduce central AC load, a model of operation on peak must be utilized. This model has been built based on past experience with submetered air conditioners.

Model of Operating Modes

The model parallels (but does not assume) the load patterns generated by a central air conditioner with a constant thermostat setting. An air conditioner controlled by a single set point on the thermostat will behave as shown in Figure 5. That is:

- Until it is sufficiently warm outside, the air conditioner is off.
- After the outside temperature exceeds a threshold, the AC cycles to maintain the setpoint. As the duty cycle and power draw increase, the diversified peak demand rises with temperature .
- At the temperature labeled "onset of continuous operation", (OCO), the house cooling load is exactly matched with the output of the unit.
- Above the OCO the unit runs continuously.

- When running continuously the total input rises due to increased power draw at higher condenser temperatures.

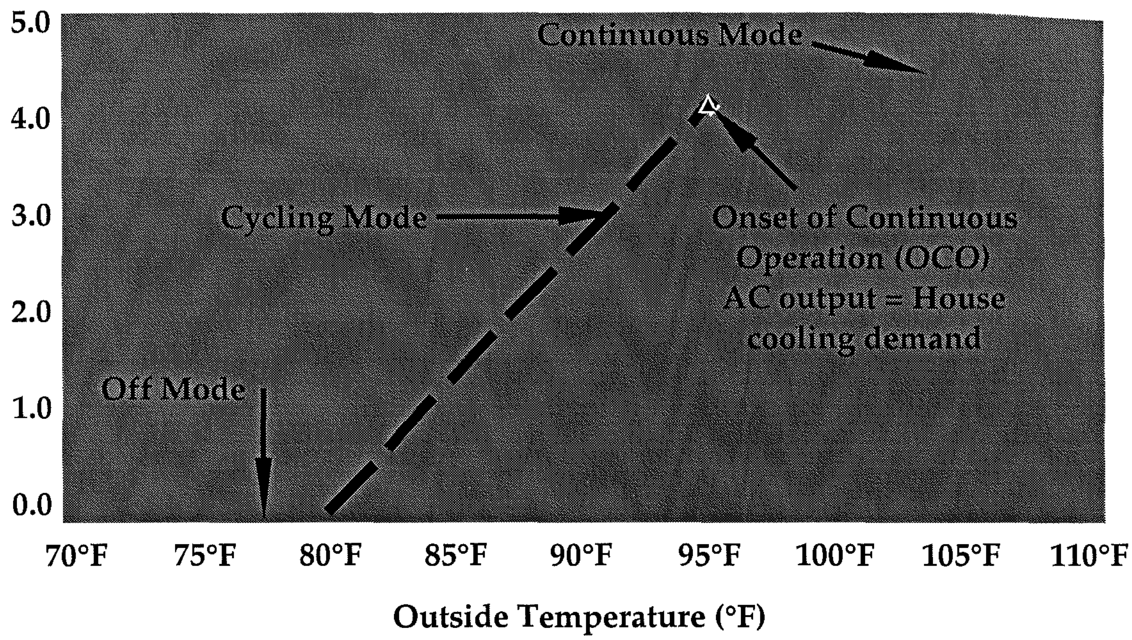

Figure 5. Modes of Operation - Individual Air Conditioner

Based on previous experience with submetered units, we can model air conditioners at peak as falling into four classes:

A	Continuous Off -	The AC is not running at all during peak.
B	Cycling -	The AC is cycling to maintain the setpoint temperature.
C	Could Cycle -	Currently the AC operates continuously at peak, but would cycle if energy efficient retrofits were performed.
D	Continuous On -	The AC is currently operating continuously and even with retrofitting would still do so

As shown in Figure 6, these modes closely parallel the behavior of a single unit illustrated in Figure 5.

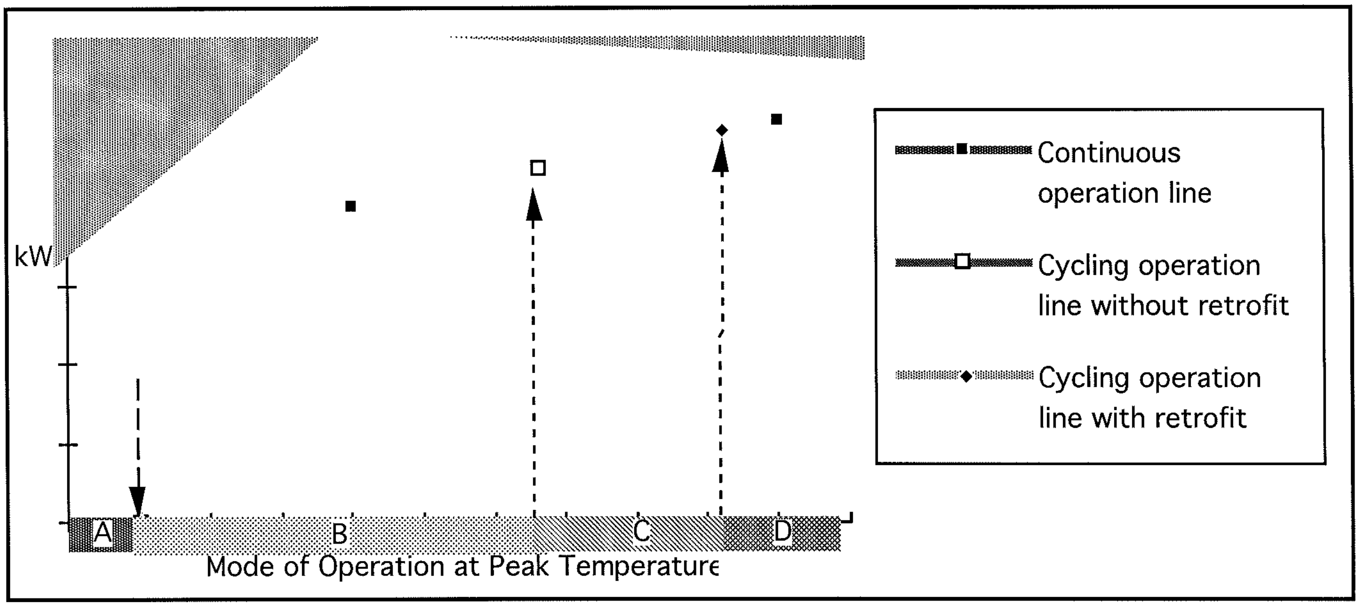

Figure 6 Air Conditioner Modes of Operation at Peak Temperature

Frequency of Operating Modes

These modes effect the potential peak reduction that can be obtained by any retrofit designed to reduce residential air conditioner peak loads. The percentages of the total number of AC units in each mode are used to calculate potential reduction. The statistical base to determine these percentages is somewhat limited. For this study, the estimates shown in Figure 7 are used based on submetered data on 100 units in Fresno.

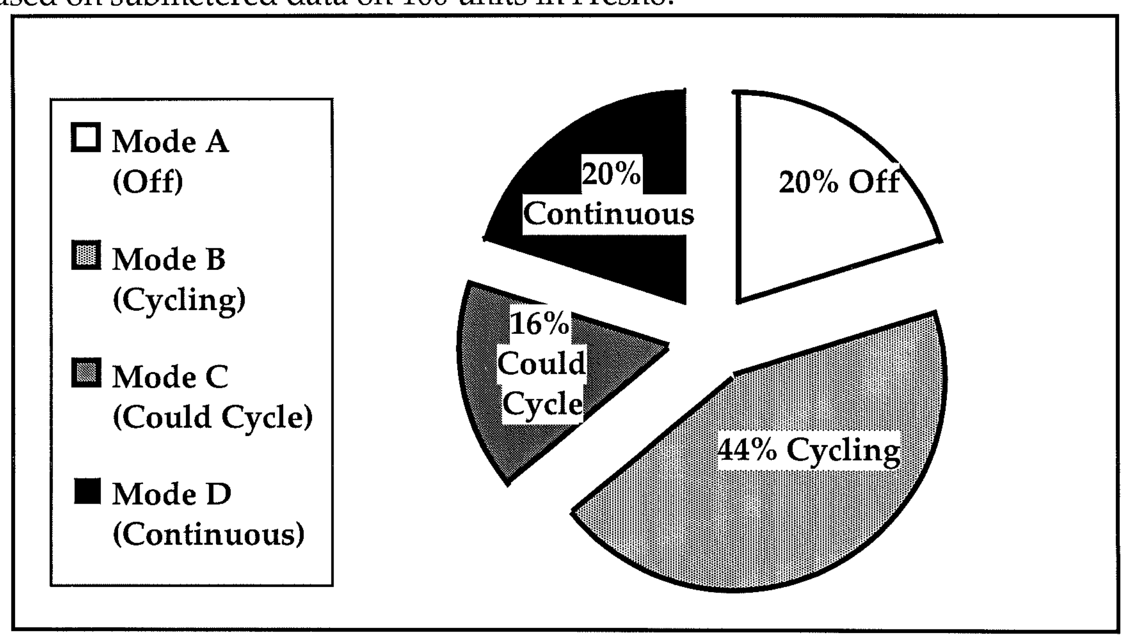

Figure 7 Frequency of Operating Modes

Thermostat Control Factor

The operating mode at peak is strongly influenced by two factors: occupant thermostat operation and AC sizing. Of these the occupant thermostat control is the most important. Previous study has shown that occupants utilized a variety of thermostat control strategies (Proctor, 1991). They are:

- Constant off
- Constant thermostat setting
- Daily set up/set down
- Manual off/on

CONSTANT OFF
With constant off control, the thermostat is always off. This may occur for a variety of reasons such as; the AC is broken, no one is home, the occupant doesn't like air conditioning even when it's hot, or s/he is trying to save money by not using the AC.

CONSTANT THERMOSTAT SETTING
With this strategy, the thermostat is set at one temperature and very rarely adjusted. When the air conditioner is controlled by a constant thermostat setting in the range 75°F to 85 °F, a large percentage of the cooling hours are characterized by the unit cycling on and off. This minimizes continuous operation of the air conditioner. This strategy may be more prevalent in retirement areas such as Paradise because residents are home during the day. Research in Fresno, across California, and in the Southern US indicate that less than 50% of the air conditioners are controlled in this manner. [3]

DAILY SET UP/SET DOWN
This strategy consists of a consistent daily pattern of setting the thermostat up in the evening and down at some time during the day, with only occasional minor adjustments of the thermostat. This pattern is common for homes in which the occupants work away from home during the day and return in the evening. When the occupant returns, the house is warm and it takes the AC a period of time to reduce the interior temperature sufficiently for cycling to begin. During the cool down period the unit may operate continuously at any outdoor temperature. This pattern appears to be a major contributor to the local area peak. It is likely that this control strategy is more prevalent in bedroom communities.

---

[3]1990 and 1991 Fresno Appliance Doctor Data, BSG/CEC Data "Occupancy Patterns and Energy Consumption in New California Houses", Reed, 1991 Energy Procram Evaluation Conference

OFF/ON
With off/on control the thermostat is manually switched on when the occupant wants it cooler and off when s/he considers it cool enough. This is accomplished with the off-cool switch on the thermostat or by adjusting the set point of the thermostat up/down. This behavior makes peak reduction by modifications to the system difficult since use is not necessarily related to ambient temperature. The AC unit may operate continuously at any temperature under the on/off control pattern. Research in Fresno indicates that approximatly 30% of the air conditioners are controlled in this mannner.

Interaction of Thermostat Control and AC Sizing to Produce Operating Mode

The operating mode is determined by a complex interaction of customer thermostat control and effective air conditioner sizing. Effective air conditioner sizing is less than the design capacity due to the condition of the air conditioner and distribution system losses. Each category contains a variety of customer households.

CATEGORY A- CONTINUOUS OFF OPERATION
An estimated 20% of customers do not operate their central air conditioner at peak. This category probably includes households where:

- House occupants are not home during peak and they keep the AC off
- House occupants are saving money by not using the AC
- The AC unit is broken
- Occupants do not like air-conditioning

CATEGORY B- CYCLING OPERATION
An estimated 44% of the households are cycling to meet the cooling load at peak. This category is expected to contain two groups based on thermostat operation and equipment sizing:

- Constant thermostat setting with an AC system that is oversized for the load.
- Off/On or Set Up/Down thermostat operation with a thermostat adjustment to a lower temperature significantly before the peak period and an oversized AC system.

CATEGORY C- COULD CYCLE
Air-conditioners in Category C run continuously during the peak, however, with sufficient load reduction, they would cycle during the peak. An estimated 16% of customers are in this group. The reduction of the duty cycle from 100% would reduce the diversified peak load.

Category C is expected to contain two groups based on thermostat operation and equipment sizing:

- Constant thermostat setting with an AC system that is now effectively undersized but would be oversized if the cooling load were reduced or the effective cooling capacity were increased.
- Off/On or Set Up/Down thermostat operation with a thermostat adjustment to a lower temperature somewhat before the peak period. This is combined with a unit that would be oversized if the cooling load were reduced or the effective capacity increased.

CATEGORY D- CONTINUOUS ON
Category D air conditioners run continuously during the peak and, even with load reductions or efficiency improvements, would continue to run continuously at peak. An estimated 20% of customers are in this group. The AC duty cycle of these customers will be 100% both before and after retrofits.

Category D is expected to contain two groups based on thermostat operation and equipment sizing:

- Constant thermostat setting with an AC system that is significantly undersized for the load.
- Off/On or Set Up/Down thermostat operation with the thermostat set point reduction occurring near or during the peak period. The AC operates to pull down the house temperature during the peak. Even with load reductions or efficiency improvements cycling would not occur until after the peak. These units could be undersized to somewhat oversized.

B. RESIDENTIAL AIR CONDITIONER PEAK SAVINGS ANALYSIS

Potential Measures

In this analysis five groups of potential measures are considered:

1. High Efficiency AC Replacement
   Replacement of existing low and moderate efficiency air conditioners with high efficiency units that provide the same level of cooling at reduced power consumption.
2. Downsized AC Replacement
   Replacement of existing oversized units with downsized units of the same efficiency.

This measure is possible because the existing systems are often oversized for the load. Since the consequences of undersizing can be severe for the contractor (potentially an expensive call-back and unit replacement) the contractors prefer to error on the side of larger units. For homes that have had effective cooling load reduction retrofits, the air conditioners are further oversized.

3. AC Repairs
   AC repairs that improve the efficiency of the unit. These repairs may also increase the power draw. For example properly charging an undercharged unit increases both cooling capacity and power draw.
4. Building Shell Measures
   Building shell measures that reduce heat gain. These measures may reduce the duty cycle.
5. Distribution System Measures
   Distribution system measures that improve the efficiency of cool air delivery to the structure. This increases the effective capacity and may reduce the duty cycle.

Interactive Effects with Operating Mode

Whether or not a reduction of the cooling load or improvement of AC system efficiency will translate into a corresponding reduction in peak depends on the operating mode of the air conditioner. That in turn depends on both the system as it exists and the pattern of thermostat operation. The effects of these interactions are to lessen the peak reduction from what has traditionally been projected. A matrix of these effects is shown in Table C.

Table C Peak Reduction by Operating Mode

Retrofit	Operating Mode Const Off **A**	 Cycling **B**	 Could Cycle **C**	 Const On **D**
High Efficiency AC Replacement	None	Good	Good	Good
Downsized AC Replacement	None	None	Varies	Good
AC Unit Repairs	None	Moderate	Varies	Varies
Building Shell Improvement	None	Good	Moderate	None
Distribution System Improvement	None	Good	Moderate	None

For all retrofit options Category A customers will achieve no peak reduction. The high efficiency AC replacement is the only retrofit that will achieve significant peak reduction for all three (B, C, and D) operating modes. Building shell and distribution system measures will achieve their full potential peak reduction on Category B customers and will achieve no peak reduction on Category D customers.

Primary Strategy

Based on this analysis, the primary strategy for reducing residential central AC local peak loads in the Paradise area is a combination of cooling load reduction and AC downsizing with efficiency improvement.

IV. Targeted DSM Peak Reduction Potential

The detailed analysis of the selected measures is summarized in Appendix B. For each measure the unit peak reduction is estimated based on AMP, other use data, empirical or theoretical peak reduction data, and operating mode where applicable. The peak reduction potential is calculated based on RASS saturation data and a market penetration estimate which takes into account previous DSM work. Table D lists the peak reduction potential under aggressive market penetrations.

Table D Peak Reduction Potential, Delivery Mechanism, and Market Penetration

DSM Program	Delivery Mechanism	Market Penetration	Peak Reduction (kW) Unit	Total
Res. Central AC downsized replacement with heat gain reduction	Direct Install with customer co-payment	25%	1.259	1,552
Res. window AC replacement	Special Rebates	35%	0.714	262
Res. Refrigerator replacement	Special Rebates	25%	0.176	336
Res New Construction	Incentive Payment	50%	0.804	996
Comm. Special Projects	Rebates	N.A.	N.A.	200
Small Commercial	Direct Install	15%	1.455	268
Cool Room DC	Direct Install & Incentives	25%	3.079	2,847

The first six programs could form the base of "firm and provable" peak reduction. The seventh program, the "Cool Room" direct central AC control, could provide a safety margin in the first three years and allow for an additional two years of delay.

The year by year cumulative local peak reduction based on implementation beginning in the summer of 1993 is shown in Table E.

Table E Cumulative Potential DSM "Capacity" in Paradise Area

Load Reduction kW/Year						
DSM Program	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Res. Central AC downsized replacement with heat gain reduction	517	1035	1552	1552	1552	1552
Res. window AC replacement	87	175	262	262	262	262
Res. Refrigerator replacement	112	224	336	336	336	336
Res New Construction	166	332	498	664	830	996
Comm. Special Projects	67	133	200	200	200	200
Comm. Window Film	89	179	268	268	268	268
Total Firm Reductions	**883**	**2078**	**3117**	**3283**	**3449**	**3615**
Cool Room DC	949	1898	2847	2847	2847	2847
Total Firm & DC	**1832**	**3976**	**5964**	**6130**	**6296**	**6462**
Potential Capacity Shortfall	*0*	*186*	*1566*	*2945*	*4325*	*5704*

Sufficient peak reduction potential exists in the Paradise area to delay the Substation upgrade, if the programs are aggressively and successfully marketed, and if they could be brought on line in the summer of 1993. Such a program would be reasonable only if the measures are also cost effective.

V. Targeted DSM Cost Effectiveness

The cost effectiveness analysis consists of a Total Resource Cost test. The net present value of generation capacity, bulk transmission, marginal energy, local distribution, and local transmission is calculated. That figure is compared to the total resource cost including all PG&E costs as well as customer costs.

Table F Total Resource Costs and Benefits*

DSM Program	Total Resource Benefits	Total Resource Costs	Benefit/Cost Ratio
Res. Central AC downsized replacement with heat gain reduction	$1,233/unit	$1,593/unit	0.77
Res. window AC replacement	$488/unit	$248/unit	1.96
Res. Refrigerator replacement	$274/unit	$299/unit	0.92
Res New Construction	$1,120/unit	$628/unit	1.78
Comm. Special Projects	N.A.	N.A.	1.0
Small Commercial	$1,058/kW	$925	1.14
Cool Room DC	$1,229	$1,082	1.14

* Approximate values based on certain simplifying assumptions, see Appendix B.

Two of the individual programs do not pass the Total Resource Cost test.

VI. Conclusions and Recommendations

The purpose of this study was to determine the feasibility of implementing a targeted T&D DSM project which could successfully delay adding Substation capacity. There is sufficient DSM potential in the load on the Paradise Substation to delay capacity addition for three to five years. A five year delay would require an expenditure of approximately $5.2 million and could achieve a 6,462 kW load reduction. Two of the major components of the project are not cost effective according to the resource cost test in Appendix B.

Such an effort would require an aggressive marketing effort under a very tight timeline. Implementation would have to begin in the summer of 1993. PG&E is under regulatory constraint to not begin any DSM for T&D benefits until the Model Energy Communities (MEC) program evaluation is complete. The final MEC evaluation is not expected within the time frame necessary for the Paradise Substation expansion.

Due to cost effectiveness, regulatory, and timing issues we recommend that PG&E not proceed with a targeted T&D DSM project for Paradise at this time.

The overall methodology of this analysis could be integrated into a format easily usable by PG&E for future screening of potential T&D DSM projects. Development of that package would reduce the time and cost associated with such a screening.

We recommend that the analysis methodology be further refined by additional data on AC customers, homes, and loads.

The AC model used in this analysis provides increased clarity and confidence in projections of residential AC peak reductions.

Since the "Cool Room" concept appears cost effective, it should be investigated for use in other areas.

When equipment must be ordered two years in advance, a lead time of three years for targeted T&D DSM implementation is required. This will change only if rapid validation is accepted or DSM proves to be as reliable as an equipment upgrade.

Appendix A

Bibliography and References

ASHRAE, ASHRAE Fundamentals, American Society of Heating Refrigerating, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, NE, Atlanta, GA 30329, 1991.

American Painting Contractor, New coating "film" technology reduces building energy use, American Painting Contractor, Vol. 69 No. 5, P.O. Box 8803, Boulder, Colorado 80328, May 1992.

Berkeley Solar Group, Occupancy Patterns and Energy Consumption in New California Houses (1984-1988), California Energy Commission, Sacramento , CA. September 1990.

Brodsky, Joel B., and Susan E. McNicoll, Pacific Gas And Electric Company Residential Appliance Load Study, 1985-1986, Appliance Metering Project, Regulatory Cost of Service Department, Pacific Gas And Electric Company, September 1987.

Carrier, Products and Systems 1991 Master Catalog, Carrier Corporation, Syracuse, New York.

Carrier, The Blue Book of Air Conditioning, Reference Guide to Air Conditioners and Heat Pumps 1967-1987, Carrier Corporation, P.O. Box 4808, Syracuse, New York, 13221, 1988.

Davids, Bradley J. P.E., Taking the Heat out of Sunlight - New Advances in Glazing Technology for Commercial Buildings, American Council of an Energy Efficient Economy 1990 Summer Study, Reprint

General Electric, GE Room Air Conditioners The 1993 Line, Pub. No. 26-S042, General Electric Company, Louisville, Kentucky 40225, Sept. 1992.

Granda, Christopher A., A Statistically Based Impact Evaluation of a Direct Install Compact Fluorescent Distribution Program, ACEEE 1992 Summer Study on Energy Efficiency in Buildings, pages 4.63-72, American Council for an Energy Efficient Economy, 1001 Connecticut Avenue, NW, Suite 801, Washington DC 20036, August 1992.

Huang, Y.J., H.F. Wu Ph.D., and J.W. Hanford, The Energy and Comfort Performance of Evaporative Coolers for Residential Buildings in California Climate, ASHRAE Transactions 1991, V. 97 Pt 2, American Society of Heating

Refrigerating, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, NE, Atlanta, GA 30329, 1991.

Klimovich, Risto, We know what "R" value is but have you heard of "a" value?, American Painting Contractor, Vol. 69 No. 5, P.O. Box 8803, Boulder, Colorado 80328, May 1992.

Lawrence Berkeley Laboratory, Cool Glazings for Residential Retrofit, Buildings Technologies Group, M.S. 90/3147, Lawrence Berkeley Laboratory, Berkeley, CA 94720, January 1993.

National Oceanic and Atmospheric Administration, Climatological Data California, Volume 94 Number 6-8, National Oceanic and Atmospheric Administration, National Climatic Data Center, Federal Building, Asheville N.C., 28801, 1990.

Orans, Ren, Targeted T&D Load Deferral Project, Model Energy Communities (Delta Project) Program, Individually Targeted Residential Efficient A/C Early Replacement and Downsizing, Draft report.

Orans, Ren, C.K. Woo, Joel N. Swisher & PG&E, Targeting DSM for T&D Benefits: A Case Study of PG&E's Delta District, Pacific Gas and Electric Company, 77 Beale Street, San Francisco, CA, December 1991.

Pacific Gas and Electric Company, Annual Summary Report on Demand Side Management Programs in 1991 and 1992, Pacific Gas and Electric Company, March 1992.

Pacific Gas and Electric Company, Potential Estimator Spreadsheet - Trialized with Paradise Substation Data, internal document, PG&E, CEE, 1991.

Pacific Gas and Electric Company, 1990 Residential Appliance Saturation Survey, Catalog of Saturations, Pacific Gas and Electric Company, Marketing Planning and Research Department, Market Research and Information Section, October, 1991.

Pacific Gas and Electric Company, 1993 Retrofit Express Program (Non-Residential Retrofit) Economic and Technical Assessments, Pacific Gas and Electric Company, Energy Efficiency Services Department, Commercial, Industrial and Agricultural Programs, November, 1992.

Parker. D.S., et. all, Measured Air Conditioning Electricity Savings from Reflective Roof Coatings Applied to Florida Residences, FSEC-CR-596-93 The Building Design Assistance Center, Florida Solar Energy Center, 300 State Road 401, Cape Canaveral, Florida 32920, February 1993.

Parker, Danny S., and Ted C. Stedman, Measured Electricity Savings of Refrigerator Replacement: Case Study and Analysis, ACEEE 1992 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, 1001 Connecticut Avenue, NW, Suite 801, Washington DC 20036, August 1992.

Proctor, John, Pacific Gas and Electric Appliance Doctor Pilot Project Proctor Engineering Group, 5725 Paradise Drive Suite 820, Corte Madera, CA 94925, January, 1991.

Proctor, John, and Dutt Ph.D., Gautum, Pacific Gas and Electric Residential Refrigerator Field Metering Project Final Report 1991 Case Studies, Proctor Engineering Group, 5725 Paradise Drive Suite 820, Corte Madera, CA 94925, May 1992.

Proctor P.E., John, and Downey, Tom, Refrigerator Rebate Evaluation 1992 Field Metering Report, Report number RAE-92-BO6, Measurement and Evaluation Planning Section, Energy Efficiency Services Department, Pacific Gas and Electric Company, San Francisco, CA, November 1992.

Quantum Consulting Inc., Pacific Gas and Electric Company's Model Energy Communities (MEC) Program Phase I Evaluation, Draft, Quantum Consulting Inc., December, 1992.

Reed, John H., Physical and Human Behavioral Determinants of Central Air-Conditioner Duty Cycles, Oak Ridge National Laboratory, Oak Ridge, TN Proceedings from 1991 Energy Program Evaluation Conference, Chicago

Selkowitz, S.E., and Lampert, C.M., Application of Large-Area Chromogenics to Architectural Glazings, Lawrence Berkeley Laboratory, Applied Science Division, University of California, Berkeley, CA 94720, June 1989.

Appendix B

Analysis of Primary Peak Reduction Strategies

These calculations were a first-cut approximation to determine potentially interesting measures. A number of simplifying assumptions were made in the calculation of the Total Resource Costs (TRC) and Net Present Value (NPV) of Benefits. The sensitivity of the Cost Effectiveness calculations to these assumptions must be considered when reviewing this section.

The customer discount rate for funds is estimated as 15%. Early replacement calculations are very sensitive to this assumption. For instance if the estimate of the discount rate is lowered to 11%, The NPV of Benefits/Costs ratio of early refrigerator replacement would be raised from 0.92 to 1.30. The ratio for early replacement of central air conditioners would be raised from 0.77 to 0.88.

PG&E administrative expenses are estimated from reported results of other programs but could differ significantly from these. Savings for generation capacity are based only on summer peak reduction; no credit is given for winter part peak reductions. The marginal energy cost benefits are set equal to the annual average and not divided into winter and summer peak periods.

Residential Central AC: Downsized replacement with moderate load reduction

Connected Load Reduction- Unit Level:	**2.701 kW/unit**
Assumptions:	
Existing AC size:	3.43 tons
Existing AC EER at 105°F	7.0
Replacement AC size	2.75 tons
Replacement AC EER at 105°F	10.38
Peak Reduction- Paradise Area:	**1,552 kW**
Assumptions:	
Paradise area peak reduction per unit	1.259 kW/unit
Total CAC population:	5,892 units
Units over 5 yrs old	83.7% (4,932 units)
Market penetration	25% (1,233 units)
Peak Reduction- System:	**1,191 kW**
Assumptions:	
System/local load ratio PM)	0.767 (AMP Study 3:30/5:30
System peak reduction per unit	0.966 kW/unit
Energy Savings- Building or Unit Level:	**436 kWh/year**
Assumptions:	
Average kWh usage per unit	1,307[4] kWh/unit
Existing SEER	8
Replacement SEER	12
Energy Savings- System Level:	**537,600 kWh/year**
Cost Effectiveness - TRC:	**$1,593/unit**
Assumptions:	
AC unit installed (2.75 ton, SEER=12)	$1,759/unit[5]
Standard AC unit (3.43 ton, SEER=10)	$1,680/unit[6]
Regular replacement in 5 years	
Equipment inflation rate	4%
Customer discount rate	15%

[4]Conditional Demand Analysis 1990

[5]MEC data: $281.33 * Tons + $852.33; 1992 dollars inflated at 4%/year

[6]MEC data and 1993 Retrofit Express Program: $40/Ton-SEER 1993 dollars, inflated to $41.60

NPV of future replacement cost	($1,016/unit)
Incremental cost of high eff. AC	$79/unit
Load reduction	$400/unit
RACER[7] & contractor admin	$400/unit
PG&E admin.	$50/unit

Cost Effectiveness - NPV of Benefits **$1,233**

Assumptions:

The high efficiency AC unit (2.75 ton, SEER=12) replaces the existing AC (3.43 ton, SEER=7) for 5 years. Thereafter, it replaces a standard replacement AC (3.43 ton, SEER=10) for years 6 through 18.

Generation capacity	$107
Bulk transmission	$83
Marginal energy	$123
Local area distribution	$771
Local area transmission	$150
Total NPV of benefits	$1,233

Cost Effectiveness - NPV of Benefits/Costs **0.77**

Total PG&E Program Costs: **$2,600,000**

Assumptions:

Program costs	$850/unit
AC unit installed	$1,759/unit
Customer co-payment	$500/unit
PG&E costs	$2,109/unit
Number of units	1,233 units

Reliability - High

The changes are 'hard-wired' and the connected load is reduced.

Persistence - High

The peak reduction and energy savings will tend to last the life of the equipment, estimated at 18 years. By the time of replacement, the newer energy standards will assure that most of the savings remain even after the equipment is replaced.

Interaction - Mixed

Interation is high with occupant control of thermostat. This is integrated into the model. There is a small interaction with the refrigerator replacement measure.

---

[7]Residential Air Conditioner Early Replacement program

Benefits to Participants

Energy savings: Approximately one third of annual cooling costs.
Capital cost reduction: Replacement of an older unit at a reduced cost.

Disadvantages to Participants

Cooling capacity reduction: With proper sizing will not be a problem except during the cool down period with Up/Down thermostat operation. This can be mitigated with a clock thermostat.

Residential Window AC High Efficiency Replacement

Non-Diversified Load Reduction- Unit Level:	**0.874 kW/unit**
Assumptions:	
Average AC size:	18,000 Btu/hour
Existing AC EER	6.5
Replacement AC EER	9.5
Peak Reduction- Paradise Area:	**262 kW**
Assumptions:	
Existing diversified demand	2.263 kW/unit[8]
Diversified demand factor	0.817
Paradise area peak reduction per unit	0.714 kW/unit
Existing market size:	1,049 units
Market penetration	35% (367 units)
Peak Reduction- System:	**219 kW**
Assumptions:	
System/Local demand factor	0.8356[9]
System peak reduction per unit	0.597 kW/unit
Energy Savings- Building or Unit Level:	**144 kWh/year**
Assumptions:	
Average kWh usage per unit	504 kWh/year-unit[10]
Existing SEER	7.5
High efficiency SEER	10.5
Standard new SEER	9.8

---

[8] Appliance Metering Project
[9] Appliance Metering Project: Window AC 3:30/5:00 PM diversified demand
[10] Conditional Demand Analysis 1990

Energy Savings- System Level:	**53,400 kWh/year**
Cost Effectiveness - TRC:	**$248/unit**
Assumptions:	
High Eff. Window AC unit (EER=9.5)	$555/unit
Standard AC unit (EER=8.8)	$520/unit
Regular replacement in 5 years	
Equipment inflation rate	4%
Customer discount rate	15%
NPV of future replacement cost	($315/unit)
Incremental cost of high eff. AC	$35/unit
Installation (self-installed)	$0/unit
PG&E admin.	$8/unit[11]

Cost Effectiveness - NPV of Benefits **$488**

Assumptions:

The high efficiency AC unit (EER=9.5) replaces the existing AC (EER=6.5) for 5 years. Thereafter, it replaces a standard replacement AC (EER=8.8[12]) for years 6 through 18.

Generation capacity	$39
Bulk transmission	$36
Marginal energy	$53
Local area distribution	$302
Local area transmission	$59
Total NPV of benefits	$488

Cost Effectiveness - NPV of Benefits/Costs **1.97**

Total PG&E Program Costs:	**$106,000**
Assumptions:	
Program costs	$8/unit
Window AC unit	$555/unit
Installation (self-installed)	$0/unit
Customer co-payment	$278/unit
PG&E costs	$285/unit
Number of units	367 units

Reliability - High

The changes are 'hard-wired'. The connected load is reduced.

[11] PG&E Average administrative cost for residential appliance efficiency 1.5% of program expense, PG&E Annual Summary of DSM Programs - March 1992

[12] EER modeled equal to Carrier APM15DA

Persistence - High

Interaction - None with other measures

Benefits to Participants

Energy savings: Approximately one third of annual cooling costs.
Capital cost reduction: Replacement of an older unit at a reduced cost.

Disadvantages to Participants

None

Residential Refrigeration   High Efficiency Early Replacement

Diversified Peak Reduction- Unit Level:	**0.176 kW/unit**
Assumptions:	
10+ yr. refrig:	0.288 kW of coincident peak[13]
New high eff:	0.112 kW " "[14]
Average primary refrig	0.174 kW " "
Average 2nd & 3rd refrig	0.288 kW " "
Average all refrig	0.200 kW " "
Peak Reduction- Paradise Area:	**336 kW**
Assumptions:	
Total number of households	16,085 (1990)
Percent with 1 refrig	71.6%[15]
Percent with 2 refrig	25.3% (RASS)
Percent with 3 refrig	2.6% (RASS)
17.1% of first refrigerators and all second and third refrigerators are assumed to be 10+ years old	
10+ yr. old refrig:	7,643 units
Market penetration	25% (1,911 units)
Peak Reduction- System:	**387 kW**
Assumptions:	
System peak reduction per unit	0.203 kW/unit

[13]Appliance Metering Project

[14]John Proctor, metered data - unpublished interim results of PG&E 1992 Refrigerator Rebate Evaluation.

[15]RASS data for Paradise local office

Energy Savings- Unit Level:	**1297 kWh/unit/year**
Assumptions:	
10+ yr. old refrig:	1980 kWh/year
New high eff	683 kWh/year
Energy Savings- System Level:	**2,479,000 kWh/year**
Cost Effectiveness - TRC:	**$299/unit**
Assumptions:	
High Eff. Refrigerator	$750/unit
Regular replacement in 5 years, the cost and efficiency of the future replacement are assumed equal to the current replacement, 1993 appliance efficiency standard	
Equipment inflation rate	4%
Customer discount rate	15%
NPV of future replacement cost	($454/unit)
Installation (self-installed)	$0/unit
PG&E admin.	$3/unit[16]
Cost Effectiveness - NPV of Benefits	**$274**
Assumptions:	
The high efficiency refrigerator replaces the existing refrigerator for 5 years. Thereafter, the new unit and standard replacement are equivalent.	
Generation capacity	$9
Bulk transmission	$10
Marginal energy	$185
Local area distribution	$59
Local area transmission	$12
Total NPV of benefits	$274
Cost Effectiveness - NPV of Benefits/Costs	**0.92**
Total PG&E Program Costs:	**$388,000**
Assumptions:	
Program costs	$3/unit
Refrigerator	$750/unit
Installation (self-installed)	$0/unit
Customer co-payment	$550/unit
PG&E costs	$203/unit
Number of units	1,911 units

[16] PG&E Average administrative cost for residential appliance efficiency 1.5% of program expense, PG&E Annual Summary of DSM Programs - March 1992

Reliability - High

Persistence - High
Eventual replacement units are likely to be at least as efficient as these units.

Interactions - Moderate
If the unit is located in an air-conditioned space, the air-conditioner will reduce the refrigerator load (lowering the peak reduction). The more efficient refrigerator will reject less heat to the structure which will improve peak reduction. **Benefits to Participants**

Energy savings: Approximately half of the annual refrigeration costs.
Capital cost reduction: Replacement of an older unit at a reduced cost.

Disadvantages to Participants
None

Residential New Construction

Four measures over and above Title 24 standards are primary in this strategy:
1. Permanently sealing the duct work with mastic
2. Selective solar control glazing on the West windows
3. Proper installation of a high efficiency air conditioner
4. Correct sizing of the air conditioner

The residential new construction project is modeled to be continuously on-going until at least the time of the substation expansion.

Diversified Load Reduction- Unit Level:	**0.804 kW/unit**
Assumptions:	
Standard AC size:	3.43 ton
Correct AC size:	2.75 ton
Standard AC EER	8.28 EER
High eff. AC	10.38 EER
Peak reduction due AC	0.680 kW
Standard glazing	1.0 SC
Solar control glazing	0.49 SC
West window area	44.8 sq. ft.
Solar load at 5:30 PM	216 Btu/sf-hr
Mass coefficient factor	0.65
External shading etc.	50%
Percent of AC units On	80%

Peak Reduction- Paradise Area:	**166 kW/year**
Assumptions:	
Paradise area peak reduction per unit	0.8036 kW/unit
Existing market size:	413 units/year
Market penetration	50% (206 units)
Peak Reduction- System:	**127 kW/year**
Assumptions:	
System/Local demand factor	0.767
System peak reduction per unit	0.6164 kW/unit
Energy Savings- Building Level:	**262 kWh/year**
Assumptions:	
Average kWh usage per unit	1307 kWh/year-unit
Standard AC	10.0 SEER
High efficiency AC	12.0 SEER
Solar load	20,083 Btu/sf-year[17]
Energy Savings- System Level:	**(54,000 kWh/year)/year**
Cost Effectiveness - TRC:	**$628/unit**
Assumptions:	
AC unit installed (2.75 ton, SEER=12)	$1,759/unit
Standard AC unit (3.43 ton, SEER=10)	$1,680/unit
Incremental cost of high eff. AC	$79/unit
Duct sealing load reduction	$50/unit[18]
Incremental cost of selective glazing	$2/sf[19]
West window area	44.8 sf
Sizing & contractor admin	$400/unit
PG&E admin.	$10/unit[20]
Cost Effectiveness - NPV of Benefits	**$1,120**
Assumptions:	
Persistence of measure	18 years
Generation capacity	$104
Bulk transmission	$73
Marginal energy	$128
Local area distribution	$682

[17]PG&E 1993 Retrofit Express Program, pages NRR 183-185; Solar load 241 kBtu/sf-yr; cooling season 33% of solar year, 25% effectiveness

[18]Proctor Engineering Group, 2 hours X $25

[19]Deborah Hopkins, LBL.

[20]PG&E Average administrative cost for residential appliance efficiency 0.5% of program expense, incresed to $10, PG&E Annual Summary of DSM Programs - March 1992, pg. VIII-4.

Local area transmission	$133
Total NPV of benefits	$1,120

Cost Effectiveness - NPV of Benefits/Costs **1.78**

Total PG&E Program Costs: **$129,000/year**

Assumptions:

Program costs	$618/unit
PG&E admin.	$10/unit
Customer co-payment	$0/unit
PG&E costs	$628/unit
Number of units	206 units/year

Reliability - High

Changes are 'hard-wired'. The connected load is reduced.

Persistence - High

The peak reduction and energy savings will generally last the life of the equipment, estimated at 18 years. The duct sealing work and reduced air conditioner size should last the life of the structure, so 18 years is conservative.

Interaction - Customer interation modeled in analysis

Benefits to Participants

Energy savings: Approximately 20% of annual cooling costs.
Capital cost reduction: Better construction value at a reduced cost.

Disadvantages to Participants

None

Large Commercial: Individualized projects

The costs and benefits of these projects have already been studied in depth. The actual measures utilized will be dependent on the opportunities present. Refer to PG&E 1993 Retrofit Express Program, (Non-residential Retrofit) Economic and Technical Assessments.

Small Commercial: Window films on West windows

Load Reduction- Unit Level: **1.455 kW/unit**

Assumptions:

Existing AC EER at 105°F	1.3 kW/ton
Standard glazing	1.0 SC

Solar control glazing	0.49 SC
Solar load at 5:30 PM	216 Btu/sf-hr
West window area	250 sq. ft.
Mass coefficient factor	0.65
External shading etc.	25%

Peak Reduction- Paradise Area:	**268 kW**
Assumptions:	
Total small commercial accounts:	1,844 accounts
Offices and stores	66.7% of accounts
Market penetration	15% (184 units)
Peak Reduction- System:	**186 kW**
Assumptions:	
Solar load at 3:30 PM	150 Btu/sf-hr
System peak reduction per unit	1.010 kW/unit
Energy Savings- Building Level:	**832 kWh/year**
Assumptions:	
Existing AC EER at 105°F	1.3 kW/ton
Solar load	30,728 Btu/sf-year[21]
Energy Savings- System Level:	**153,000 kWh/year**
Cost Effectiveness - TRC:	**$925/unit**
Assumptions:	
Window film, installed	$3.50/sf
Average building west window area	250 sf
Installed cost	$875/bldg.
PG&E admin.	$50/unit
Cost Effectiveness - NPV of Benefits	**$1,058**
Assumptions:	
Generation capacity	$61
Bulk transmission	$63
Marginal energy	$166
Local area distribution	$642
Local area transmission	$126
Total NPV of benefits	$1,058

[21]PG&E 1993 Retrofit Express Program, pages NRR 183-185; Solar load 241 kBtu/sf-yr; cooling season 33% of solar year, 75% effectiveness

Cost Effectiveness - NPV of Benefits/Costs	**1.14**	
Total PG&E Program Costs:	**$170,000**	
Assumptions:		
Window film installed		$875/unit
Customer co-payment		$0/unit
PG&E admin		$50/unit
Number of units		184 units

Reliability - Moderate
The peak reduction and energy savings are dependent on AC operation.

Persistence - Moderate
The peak reduction and energy savings will last the life of the window film, estimated at 7 years.

Interaction - Few
Existing solar shading can substantially reduce benefits. None with other measures.

Benefits to Participants
Energy savings and reduced UV degradation of products.

Disadvantages to Participants
The reduced solar gain can increase winter heating requirements.

Residential Central AC: "Cool Room" Concept

The following analysis is based on direct control of the central AC and the alternate operation of a 8000 Btu/hr window air-conditioner. The strategy is compared against an existing EER = 7 AC.

Non-Diversified Load Reduction- Unit Level:	**5.038 kW/unit (Existing)**	
Assumptions:		
Main AC, existing:	3.43 Ton, EER = 7	
Window AC:	8000 Btu/hr, EER = 9.5	
Peak Reduction- Paradise Area:	**2,848 kW**	
Assumptions:		
Paradise area peak reduction per unit	3.079 kW/unit	
Existing CAC market size:	5,892 units -	
Units over 5 years old	83.7%	
Replacement program	Less 25% replacements	
Market penetration	25%	(925 units)

Peak Reduction- System: **0 kW**

Assumptions:

The direct control system is only operated to mitigate the local area peak. Local area peak and system peak are not co-incident.

Energy Savings- Building or Unit Level: **0 kWh/year**

Assumptions:

The amount of central AC operation interruption would be negligible. If the occupants choose to operate the high efficiency window unit instead of the large inefficient central unit a large fraction of the time, the energy savings could be significant.

Energy Savings- System Level: **0 kWh/year**

Cost Effectiveness - TRC: **$1,082/unit**

Assumptions:

Room AC	$427/unit
AC Installation	$75/unit
Switch	$165/unit
Admin.	$210/unit
Customer incentive years)	$205 (NPV of $50/year for 5

Note: The cost estimate is highly dependent on the availability of an existing direct control network.

Cost Effectiveness - NPV of Benefits **$1,229**

Assumptions:

Generation capacity	$0
Bulk transmission	$0
Marginal energy	$0
Local area distribution	$1,028
Local area transmission	$202
Total NPV of benefits	$1,229

Cost Effectiveness - NPV of Benefits/Costs **1.14**

Total PG&E Program Costs: **$1,042,000**

Assumptions:

Program costs	$1082/unit
Incentive payments	$50/year/unit
Average length of participation	5 years
Customer co-payment	$0/unit
Number of units	925 units

Reliability - Moderately High

The key to reliability is to insure that the customer enjoys a high level of comfort and has little incentive to bypass the controls. The central AC is under direct control from the utility.

Persistence - Good

Since the customer will be able to discontinue the program at any time, the key again is to insure customer comfort and satisfaction. Persistence is effected by the project administrators.

Interaction - High with alternate cooling source

This measure is not available to homes that obtain replacement units.

Benefits to Participants

Annual bill reduction in exchange for modest comfort reduction.

Disadvantages to Participants

Modest comfort reduction in exchange for annual bill reduction.

Category:

Primary measure if:

1. Direct control capability exists or can be cost effectively built.
2. Customer survey and focus groups show strong customer support.
3. Sufficient internal PG&E support exists to provide project administrators with adequate resources.
4. A one year large scale trial proves successful.