RESIDENTIAL CONSERVATION POWER PLANT STUDY

PHASE 1 - TECHNICAL POTENTIAL

Report prepared for:

Residential Conservation Services Department
Pacific Gas and Electric Company
San Francisco, CA 94106

by:

American Council for an Energy-Efficient Economy
1001 Connecticut Ave., NW
Washington, DC 20036

Howard Geller, Principal Investigator

and

Anibal de Almeida, Barbara Barkovich, Carl Blumstein,
David Goldstein, Alan Meier, Peter Miller,
Olivier de la Moriniere, Art Rosenfeld, Linda Schuck

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This report was prepared for the Pacific Gas and Electric Company (PG&E). The views expressed are those of the authors and not necessarily those of PG&E.

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Preface

The preparation of this report was very much a collaborative effort. Howard Geller of ACEEE served as principal investigator and coordinator. He authored the clothes dryer assessment, the scenarios analysis, and co-authored the air conditioner and lighting assessments with Olivier de la Moriniere and Anibal de Almeida, visiting researchers at Lawrence Berkeley Laboratory. Alan Meier of Lawrence Berkeley Laboratory and Howard Geller authored the water heating assessment. David Goldstein and Peter Miller of the Natural Resources Defense Council authored the refrigerator, freezer, and range assessments.

The policy issues section of the report was authored by Linda Schuck, consultant to PG&E and Barbara Barkovich, consultant. Carl Blumstein of the University of California, Berkeley and Art Rosenfeld of Lawrence Berkeley Laboratory assisted in organizing and reviewing the entire study. Eric Hirst of Oak Ridge National Laboratory also provided comments on an early draft.

The study could not have been possible without assistance from many individuals at PG&E. Lee Callaway conceptualized and initiated the study. Linda Schuck provided much help and guidance as project manager. Karen Lang of the Economics and Forecasting Dept. was especially helpful in providing information concerning PG&E's end-use forecast and model. Others from PG&E including Vince Baclawski, Mike Katz, Mike Koszalka, Ed Mah, Paula Rosput, Bill Smith, and Barry Wong provided valuable information and reviewed a draft report.

EXECUTIVE SUMMARY

A. Overview

This report evaluates the technical potential for cost-effective electricity savings in PG&E's residential sector. The potential savings are termed a "conservation power plant" to signify that improved end-use efficiency is one of the resource options available to the utility. This conceptual approach is in accordance with other studies conducted by PG&E.

The first step in assessing the feasibility of a residential conservation power plant is to determine its potential size and composition -- How much cost-effective conservation is potentially available? What technologies and options look most promising in terms of savings, cost-effectiveness, and commercial availability?

To answer these questions, this report examines the potential for electricity conservation in seven major residential end-uses, namely:

1) refrigerators;
2) freezers;
3) water heating;
4) lighting;
5) central air conditioning;
6) cooking;
7) clothes drying.

Together, these end-uses account for about 70% of the electricity consumed in PG&E's residential sector.

Part II of the study includes technology assessments in these seven end-use areas. Currently available and advanced technologies are evaluated on the basis of cost, electricity and peak power savings, cost-effectiveness and status. The electricity-conserving options do not involve any reduction in amenity or comfort levels.

Part III of the study develops three scenarios for electricity use in the seven end-use areas over the next 20 years. Included are a base scenario that is close to PG&E's 1985 end-use forecast, a current technology scenario assuming a higher penetration of cost-effective, energy-efficient technologies now available but not yet widely used, and a technical potential scenario assuming a high penetration of both energy-efficient products now available and advanced technologies not yet commercially available. The same overall equipment stocks and replacement rates are used in all scenarios.

The scenarios analysis shows that relative to the base case, the savings potential in the current technology scenario is 5180 GWh/yr and 1790 MW of summer peak demand by 2005. Electricity consumption in 2005 is 25% lower than in the base scenario. In the technical potential scenario, the savings potential in 2005 is 9260 GWh/yr and 3240 MW of summer peak demand. In this case, electricity consumption in 2005 is 44% lower than in the base scenario. The end-uses presenting the greatest electricity savings potential are refrigerators and lighting, while CAC offers the majority of the potential savings in peak summer demand.

B. Technology Assessments

In each technology assessment, a "baseline technology" and various electricity-conserving options are considered. The energy performance of the baseline technology is close to that for the typical appliance model currently being purchased.

The cost-effectiveness of the conservation measures is evaluated from the perspective of utility ownership, considering only the extra first cost for the efficiency measures. Programs to promote the purchase of more efficient equipment are not included in the study, nor is the potential increase in equipment usage as a consequence of lower utility bills accounted for. Cost-effectiveness is determined by comparing the costs of electricity and peak demand savings to PG&E's marginal electricity supply costs.

The options covered in the assessments include technologies now widely available in the U.S. (i.e., mass-produced and readily obtained), advanced technologies now under development or at the prototype stage, and technologies widely available in other industrialized countries but not in the U.S. In a few cases, the authors have conducted original analysis combining advanced product features to generate hypothetical advanced models.

The major conclusions from the technology assessments are presented below.

1. Refrigerators and freezers

Although considerable progress has been made in improving the efficiency of new refrigerators and freezers in recent years, the potential for further cost-effective energy savings is tremendous. By combining a variety of design options such as more efficient motor-compressors, improved insulation, and better refrigeration system design, it is possible to reduce energy consumption by as much as 85% relative to the electricity use typical of models produced in 1985 (about 1165 kWh/yr for top-freezer refrigerators). Furthermore, realizing the full savings potential from refrigerators and freezers has an average cost of saved energy of only $0.02-0.04/kWh, compared to PG&E's marginal electricity supply costs of $0.06-0.10/kWh during

1986-2005.

Most of the savings potential is not yet available in mass-produced refrigerators and freezers in the U.S. We believe, however, that commercial models exhibiting very low energy consumption could become widely available by the early-1990's if manufacturers decide to move forward. It should be noted that very efficient custom-made refrigerators are already produced in the U.S.; Japanese manufacturers also appear to be offering some highly efficient models.

2. Water heating

Electricity consumption for water heating can be reduced by 50-75% using heat pump water heaters rather than electric resistance heating. Products for realizing much of this savings potential are now commercially available and cost-effective. As long as hot water consumption is sufficiently high (40-50 gal/day), heat pump water heaters are generally cost-effective compared to the marginal electricity supply costs.

Reducing hot water demand in areas such as clothes washing and dishwashing can provide cost-effective energy savings as well. Front-loading clothes washers are a water-conserving option currently available; technologies allowing low-temperature dishwashing are expected to be available by 1990.

3. Lighting

Substantial electricity savings are technically and economically feasible in the area of residential lighting. Compact fluorescent light bulbs are now reaching the marketplace and this technology is rapidly improving. Compact fluorescent bulbs consume

60-75% less power than incandescent bulbs for the same amount of light output. They are cost-effective in commonly used lamps and fixtures (at least 1.7 hours per day).

Slightly improved incandescents are widely available and economical in low-use applications. Also, a coated incandescent bulb that provides a 50% savings compared to conventional incandescents is expected to be available in the near future.

4. Central air conditioners

Numerous technologies are available to reduce electricity consumption and peak power demand from central air conditioning (CAC) systems. Use of window film on south and west-facing windows is a cost-effective means for obtaining about a 10% reduction in cooling requirements. More efficient CAC systems providing about 30% savings compared to ordinary systems should be cost-effective on the basis of annual electricity savings in high-use applications (3000 hours/yr or more) if expected equipment price reductions are realized.

Indirect evaporative cooling is an emerging technology that shows great promise for providing on the order of 75% energy and peak power savings in residences in a cost-effective manner. Indirect evaporative cooling does not create the high indoor humidity levels experienced with ordinary evaporative coolers. It is estimated that the cost of saved energy is $0.025-0.05/kWh as long as air conditioning is needed at least 1000 hours/yr.

Thermal storage of "coolth" is another potentially attractive technique for reducing the peak power demand for air conditioning. Various systems are currently being developed and commercialized for the residential market.

5. Cooking ranges

Using simpler technologies such as increased insulation, better oven door seals, reduced thermal mass, and burner elements with less contact resistance, it should be possible to lower the electricity consumption of electric ranges by about 20% in a very cost-effective manner. Although these improvements present no significant technical challenges, it is uncertain whether ranges including a full set of individually modest efficiency improvements are commercially available at the present time.

Induction cooktops, now commercially available, are estimated to consume about 15-25% less electricity than conventional electric cooktops besides providing other major benefits. Induction cooktops are not cost-effective, however, when evaluated strictly on the basis of energy performance (i.e., credit for the other benefits must be taken in order to justify their use).

An innovative oven design, known as the bi-radiant oven, consumes about 70% less electricity than conventional ovens and is cost-effective on the basis of its cost of saved energy. Unfortunately, manufacturers do not appear to be interested in producing this oven design at the present time because of uncertain consumer response and other factors.

6. Clothes dryers

Moisture sensor and automatic termination controls are available with clothes dryers. This cost-effective feature typically results in 10-15% electricity savings. A number of innovative clothes dryer technologies are under development and some are already commercially available overseas. These include dryers with exhaust heat recovery, heat pump dehumidification dryers, and microwave dryers. The estimated electricity savings are 40% with the microwave dryer and 50-70% with the heat pump dryer, and both of these advanced technologies appear to cost-effective relative to PG&E's marginal electricity costs.

C. Scenarios Analysis

The three scenarios mentioned previously are developed by modeling equipment stocks, new purchases, and retirements along with average energy consumption year-by-year for each end-use. Most of the demographic assumptions as well as the unit energy consumption values in the base scenario are taken from PG&E's residential end-use model. The technology assessments serve as the basis for the assumptions regarding the energy consumption of new models in the current technology and technical potential scenarios. Of course, only cost-effective technologies are included in the scenarios when they are expected to be available. No attempt is made to limit the savings due to implementation problems or other constraints.

Table 1 shows the principal results of the scenarios analysis. In the base case, overall electricity consumption for the seven end-uses increases 37% between 1985 and 2005. Electricity consumption per household declines about 8% over this period. In the current technology scenario, total electricity consumption for the seven end-uses remains nearly constant during the next 20 years, and consumption per household declines 31%. In the technical potential scenario, absolute electricity consumption drops 24% between 1985 and 2005, with consumption per household falling by nearly 50%.

Table 1 - Energy consumption and peak power demand in the three scenarios

	Base Scenario	Current Technology Scenario	Technical Potential Scenario
Electricity consumption in 2005 (GWh/yr)	20,800	15,600	11,600
Peak power demand in 2005 (MW)	5,750	3,960	2,510
Change in electricity consumption (1985-2005)	+37%	+3%	-24%
Change in el. consumption per household (1985-2005)	-8%	-31%	-50%
Change in peak power demand (1985-2005)	+57%	+8%	-32%
Change in peak demand per household (1985-2005)	+5%	-28%	-55%
Change in el. consumption in 2005 relative to base scenario	--	-25%	-44%
Change in peak demand in 2005 relative to base scenario	--	-31%	-56%

Figures 1 and 2 show the savings in electricity consumption and peak power demand over time in the current technology and technical potential scenarios. The savings are determined relative to the base case scenario. As indicated in Table 1 and Figures 1 and 2, the savings potentials in the current technology scenario are 5180 GWh/yr and 1790 MW of peak demand by 2005. These are 25% and 31% reductions from the base case, respectively. A reduction in electricity consumption of 5180 GWh/yr is equivalent to the output from

Figure 1

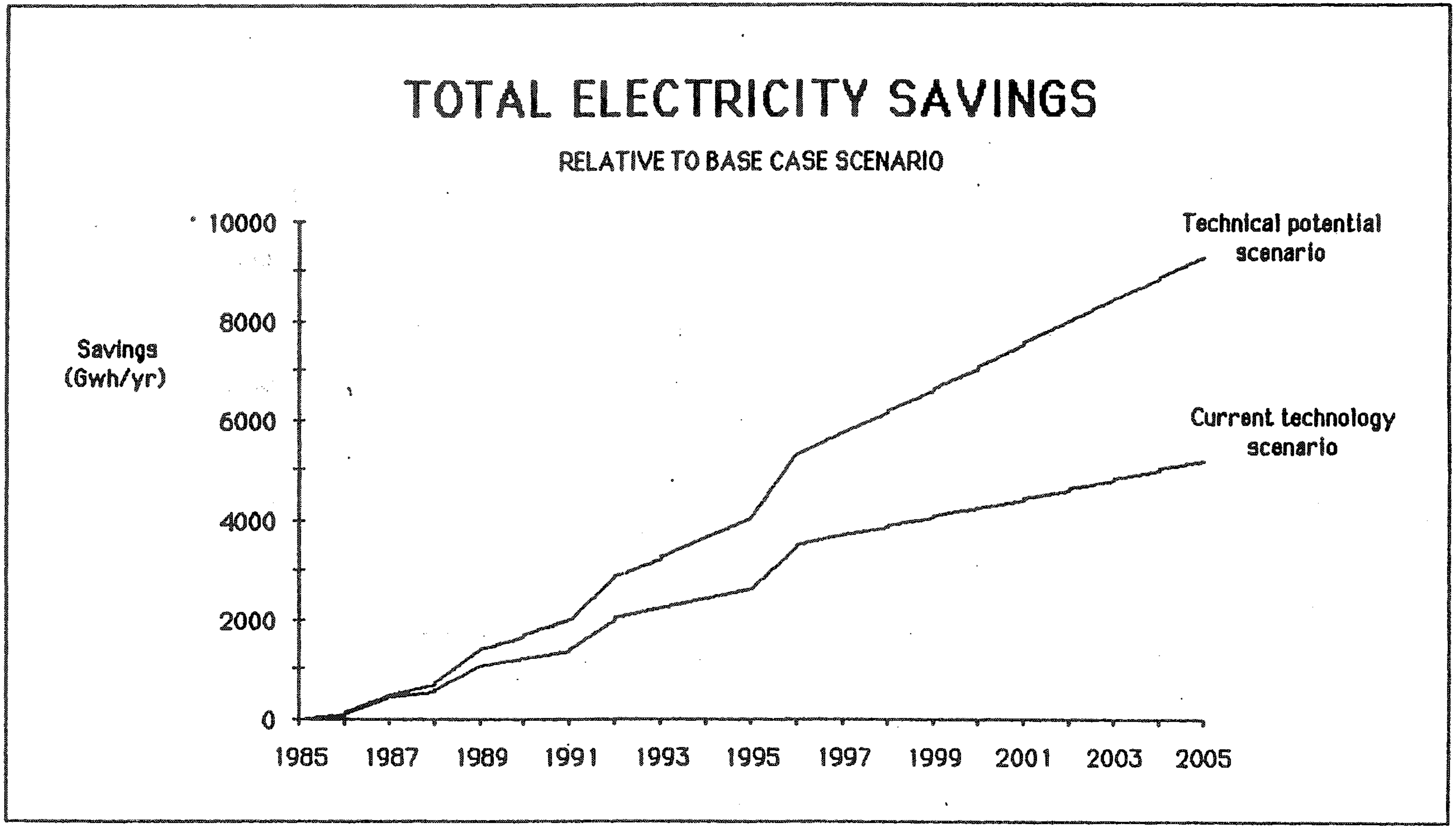
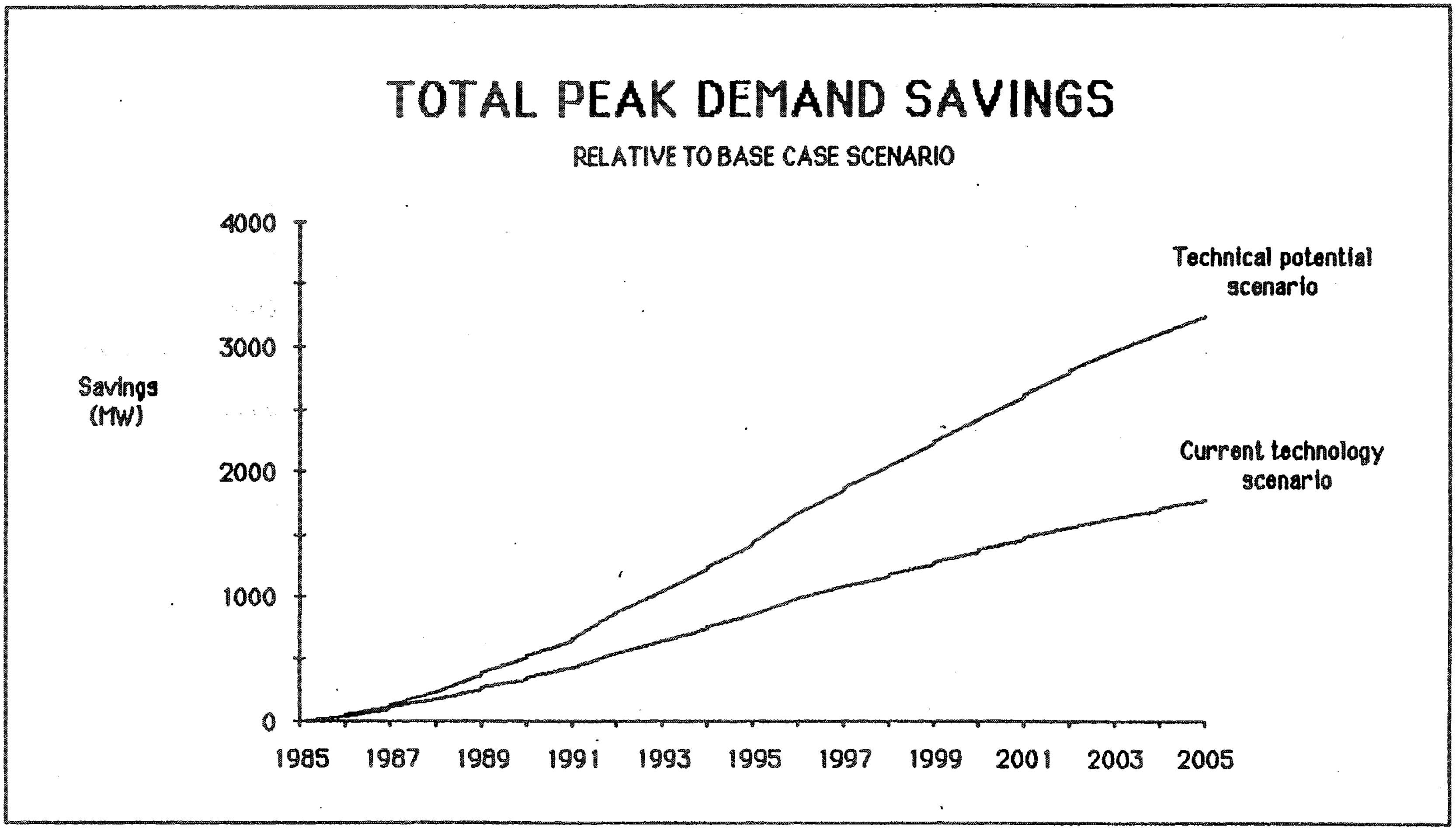

TOTAL ELECTRICITY SAVINGS
RELATIVE TO BASE CASE SCENARIO
Savings (Gwh/yr)
10000
8000
6000
4000
2000
0
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Technical potential scenario
Current technology scenario

Figure 2


TOTAL PEAK DEMAND SAVINGS
RELATIVE TO BASE CASE SCENARIO
Savings (MW)
4000
3000
2000
1000
0
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Technical potential scenario
Current technology scenario

approximately 1000 MW of baseload generating capacity.

In the technical potential scenario, the savings potentials by the year 2005 are 9260 GWh/yr and 3240 MW of peak demand, 44% and 56% reductions from the base case. A reduction in consumption of 9260 GWh/yr is equivalent to the output from about 1800 MW of baseload generating capacity.

Figures 3 and 4 show the estimated electricity consumption and peak power demand in the year 2005 by end-use and scenario. Refrigerators and lighting are the end-uses offering the greatest electricity savings potential. Lighting provides about 40% and refrigerators about 25% of the total savings in the technical potential scenario. In terms of peak power demand, air conditioning stands out, providing about two-thirds of the total savings in the technical potential scenario.

D. Qualitative Issues and Conclusion

The fourth part of the report includes a discussion of some of the qualitative characteristics of a "conservation power plant". In comparison to traditional power plants, it has a number of advantages -- shorter lead time, low risk of environmental degradation, no interest charges or capital exposure during implementation, maximum flexibility, and improved control over load shape. It would be more likely to receive regulatory approval and enhance customer relations. On the other hand, there are significant uncertainties related to the effectiveness of technologies, implementation, customer response, and changes in the regulatory and political environment. But through technical R&D as well as program experimentation and evaluation, it should be possible to limit these uncertainties to manageable levels.

Figure 3

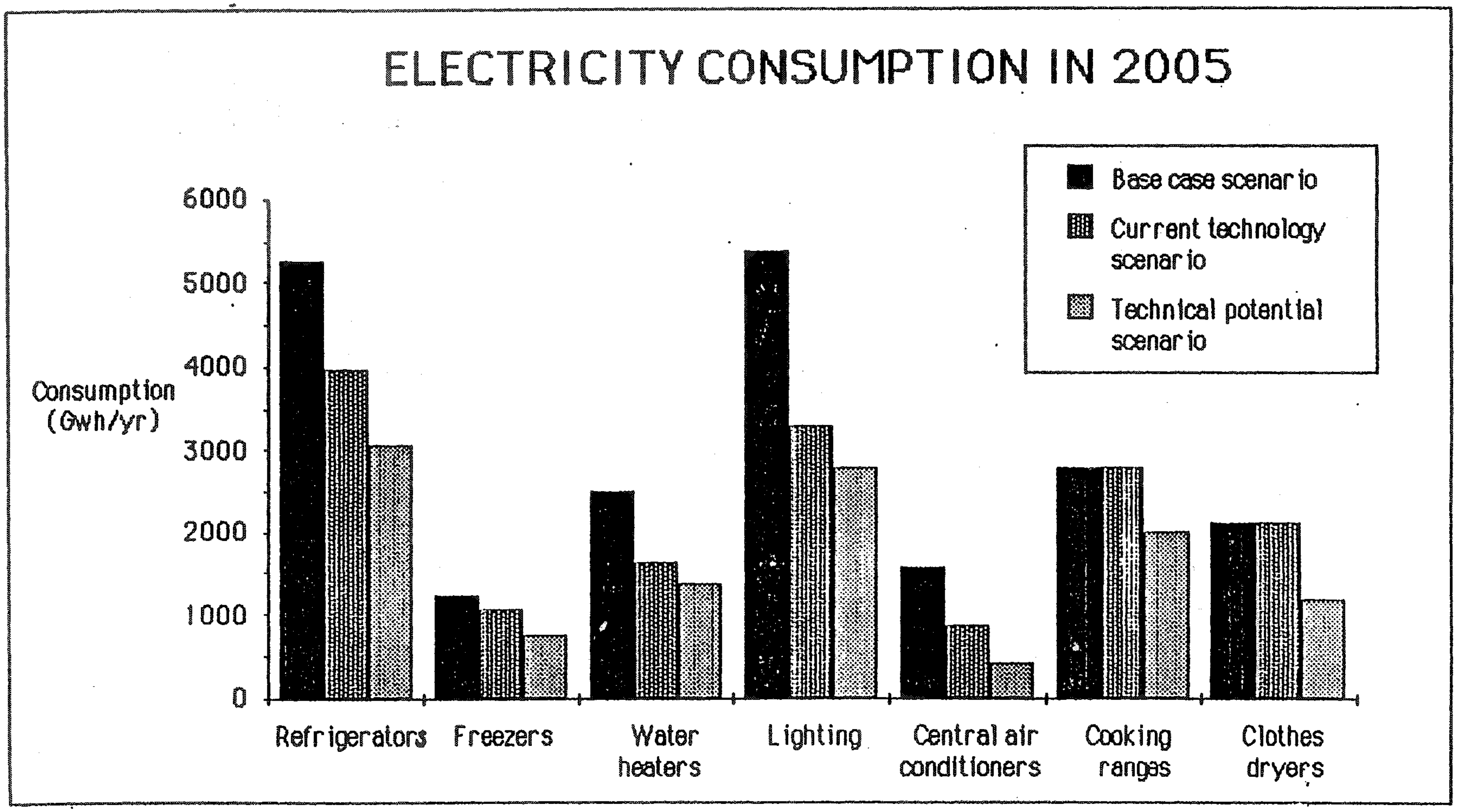
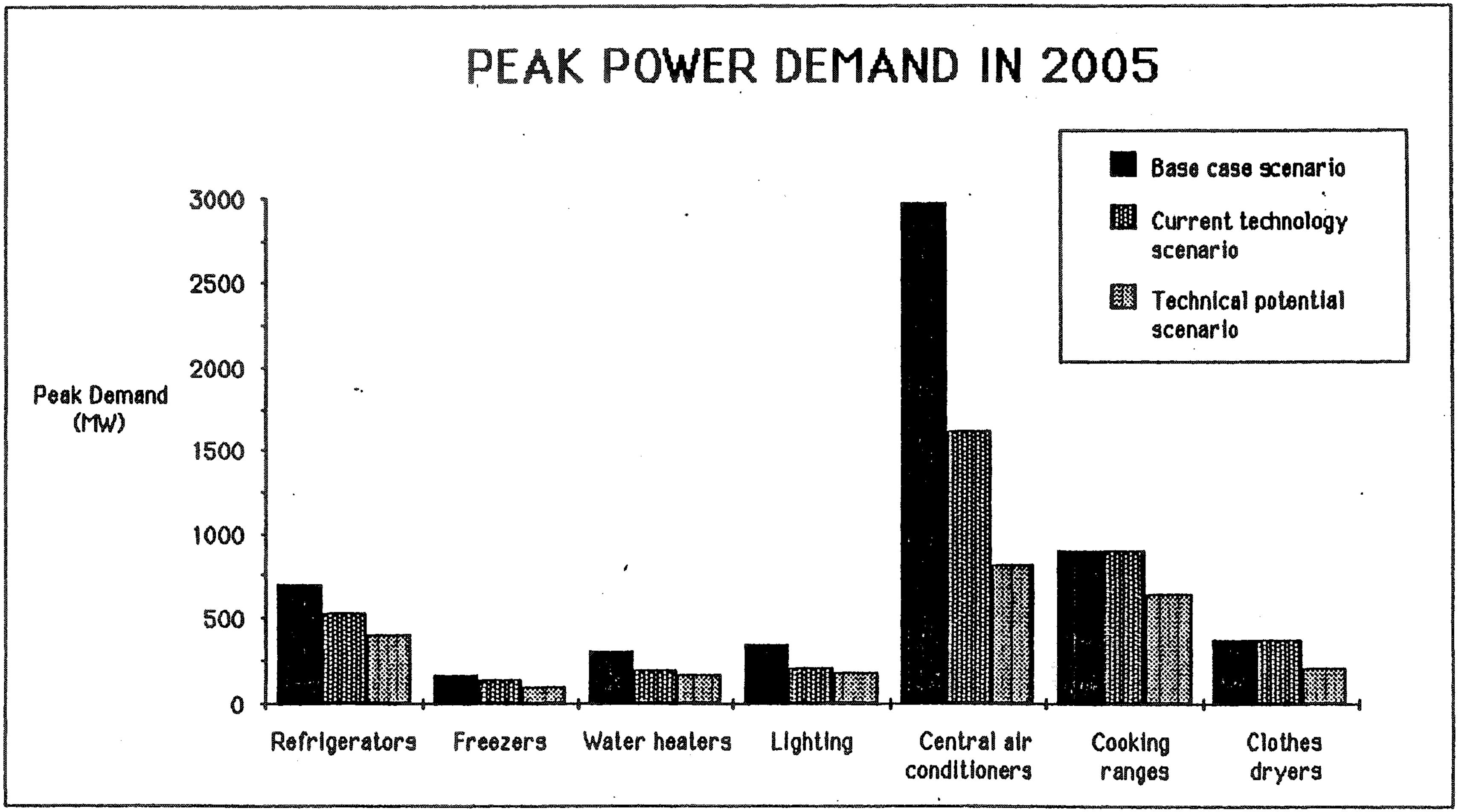

ELECTRICITY CONSUMPTION IN 2005
Base case scenario
Current technology scenario
Technical potential scenario
Consumption (Gwh/yr)
6000
5000
4000
3000
2000
1000
0
Refrigerators
Freezers
Water heaters
Lighting
Central air conditioners
Cooking ranges
Clothes dryers

Figure 4


PEAK POWER DEMAND IN 2005
Base case scenario
Current technology scenario
Technical potential scenario
Peak Demand (MW)
3000
2500
2000
1500
1000
500
0
Refrigerators
Freezers
Water heaters
Lighting
Central air conditioners
Cooking ranges
Clothes dryers

The final chapter provides recommendations for further evaluation and development of the conservation power plant. The recommendations are grouped under the headings of 1) continued scenario development; 2) program option assessment; 3) further technology R&D; and 4) intra-utility and regulatory issues.

In conclusion, it is now clear that there is substantial potential for cost-effective electricity and peak demand savings in the residential sector. Building a "conservation power plant" in this sector presents PG&E with an opportunity for minimizing the cost of energy services among its customers. The next challenge is to better define the design of the conservation power plant and the requirements for building it.

PART I - INTRODUCTION

A. Background

This report discusses the technical potential for electricity conservation in PG&E's residential sector over the next 20 years. It is the first step of the residential "conservation power plant" project initiated by PG&E's Residential Conservation Services (RCS) Department.

The project was proposed in consideration of PG&E's stated goals for avoiding large capital projects in the future, the company's present and expected electric supply situation over the next 20 years, and its commitment to offer customers cost-effective options for reducing their energy bills. Although PG&E is capacity rich in the near-term, additional generating capacity was projected to be needed starting in the late-1990's.

The RCS Department posed the question "can the additional need for energy services be met with a so-called conservation power plant"? In other words, can PG&E develop and implement additional residential conservation and load management programs that could be depended upon to reduce demand sufficiently to defer or eliminate the need for a substantial amount of new generation capacity in the next 20 years? And, could such a "conservation power plant" be cost-competitive with other resource options, both those operating now and those planned for the future?

The concept of a conservation power plant did not originate with this study. In 1983, the city of Austin, Texas, and the municipal utility there established an intent to achieve 553 MW of electricity demand savings by 1997. The collection of programs planned and developed to accomplish this goal was termed "Austin's Conservation Power Plant".

In the past, PG&E has included savings from its conservation programs in forecasts (e.g., over 1500 MW of conservation savings were included in the 1982 long-term plan). The concept of implementing a conservation power plant differs from PG&E's current collection of residential conservation programs in a number of ways. First, it is strategically designed around technical and economic opportunities and the resource needs of the company. Many of the current RCS programs, on the other hand, were designed in response to federal and state mandates rather than through an analysis of savings opportunities and consideration of the broad interests of the Company and its customers.

Second, the conservation power plant concept introduces a fundamental goal and a measure of success. Current programs have multiple, shifting, and sometimes conflicting goals. Third, by naming the collection of conservation technologies and programs a "power plant", it directly acknowledges the value of conservation to the utility and encourages comparison with other resource options.

Finally, there is an important customer relations element. We believe that by aggressively pursuing residential electricity conservation and terming it a "conservation power plant", PG&E would receive stronger support from its customers and regulators.

The first step in assessing the feasibility of a residential conservation power plant is to determine its potential size and composition -- How much cost-effective conservation is potentially available? What technologies and options look most promising in terms of savings, cost-effectiveness, and commercial availability? The purpose of this report is to answer these questions.

Seven major end-uses are considered in this study, namely:

1) refrigerators;
2) freezers;
3) water heating;
4) lighting;
5) central air conditioning;
6) cooking;
7) clothes drying.

Together, these end-uses account for about 70% of the electricity consumed in PG&E's residential sector. Other end-uses such as space heating or televisions individually account for only a small fraction of residential electricity consumption and therefore are not included in the study.

B. Report outline

The second part of the report (Chapters 2-8) contains technology assessments for the seven electrical end-uses listed above. In each assessment, various energy-conserving options are described and in most cases compared to a "base" technology. The base technology is close in energy performance to the typical appliance model currently being purchased. The factors considered for each technological option include unit energy consumption (i.e., the energy used by an individual model), first cost, cost-effectiveness, and status. Status refers to the stage of development and commercial availability of the different options.

The technical options covered in the assessments include technologies now widely available in the U.S. (i.e., mass-produced and readily obtained), advanced technologies now under development or at the prototype stage, and technologies widely available in other industrialized countries but not available in the U.S. at the present time. In a few cases, the authors have conducted original analysis combining advanced product features to generate hypothetical advanced models. All of the options examined have a high probability of being technically achievable during the next 20 years.

The third part of the report (Chapters 9-10 and the Appendices) develops various scenarios for energy consumption in the future for the seven end-uses under consideration. The scenarios developed are: 1) a base scenario which is very close to PG&E's own end-use forecast as of 1985 and includes some adoption of more efficient equipment; 2) a current technology scenario which assumes high penetration of energy-efficient technologies now widely available; and 3) a technical potential scenario which assumes a very high penetration of more efficient technologies, both currently available and advanced technologies, over the next 20 years.

In each of the scenarios, both summer peak demand (MW) and total electricity consumption (GWh) are tracked through the year 2005 by end-use. In the current technology and technical potential scenarios, neither early product retirement nor fuel switching (i.e., switching from gas-fired to electrical equipment) are assumed relative to the base case. Of course, the electricity savings potential would be greater if either of these options are pursued and included in the power plant.

The scenarios are developed by modeling equipment stocks, new purchases and retirements, and average energy consumption year-by-year for each end-use. Most of the demographic assumptions as well as the unit energy consumption values in the base scenario are derived from PG&E's residential end-use model. For the technical potential and current technology scenarios, the assumptions regarding improvements in new product efficiencies in the future are based on the technology assessments presented in Part II. The methodology is described in more detail at the beginning of Part III.

The final part of the report includes a chapter discussing some of the broad issues related to PG&E pursuing a conservation power plant instead of other resource options. The issues addressed include technological uncertainty, implementation concerns, lead time, and environmental impacts. This portion of the report is focused around the themes of uncertainty and risk.

If it is reasonable to view the technology assessments portion of this report as the definition of the building materials and components available for constructing the conservation power plant, then the current technology and the technical potential scenarios are initial examples of ways in which the materials and components might be assembled, without any limitations placed on "plant size". Of course, many other factors must be considered before a conservation power plant is implemented. The final chapter of the report includes a discussion of the next steps for developing this conservation power plant.

PART II - TECHNOLOGY ASSESSMENTS

Chapter 2 - METHODOLOGY

A. Energy and power savings

As mentioned in the introduction, a large number of technical options for reducing residential electricity consumption are examined. The options are primarily ways of increasing the energy efficiency of refrigerators, water heaters, light bulbs, and the other products. In a few cases, the options involve technical means for lowering the demand for hot water, space cooling, etc. None of the options involve reduced amenity levels or lower standards of living; they are simply "technical fixes" for conserving electricity.

The different options are evaluated in terms of both annual energy savings (kWh) and peak power savings (kW) during the summer peak demand period. Energy and power savings are based on laboratory test ratings for the most part. Studies of refrigerators show relatively close agreement between laboratory and field performance [1]. Furthermore, since we are primarily interested in estimating the difference in energy and power use between options (and not the absolute usage levels), basing the analysis on laboratory test ratings is reasonable. Also, unlike home weatherization measures where actual energy savings are highly unpredictable, it is fair to assume that installing energy-efficient appliances and lighting products will provide the anticipated savings on the average.

As part of the technology assessments, assumptions are required regarding peak load and peak savings for each end-use and technology option. Peak demand and reductions in peak demand are calculated using the overall summer peak-to-average load factors shown in Table 1. These factors were derived from load curves used by the California Energy Commission in its biennial electricity forecasts [8].

Table 1 - Assumed Equipment Lifetimes and Summer peak-to-average load factors

End-use	Lifetime[a] (yrs)	Load factor[b]
Central AC	15	16.60
Refrigerator	20	1.17
Freezer	20	1.15
Cooking	18	2.81
Water heating	13	1.08
Clothes dryer	18	1.56
Lighting	--	0.56

[a] Sources: "Staff Report on Proposed Revision on Appliance Efficiency Standards for Central Air Conditioners under 65,000 Btu/hour", Docket 84-AES-2, California Energy Commission, Nov. 1984 and "Consumer Products Efficiency Standards Economic Analysis Document", DOE/CE-0029, U.S. Dept. of Energy, 1982.

[b] Load factors based on peak demand occuring between 2:00 P.M. and 6:00 P.M. Source: 1985 CFM 6 Forecast, California Energy Commission, Aug. 1985.

There is a general concern that improvements in energy efficiency can lead to a "takeback effect" whereby the consumer responds to reduced electricity bills in part by increasing equipment use, which in turn lowers the energy savings [3]. This could occur with air conditioning and water heating, but is not likely to be a problem with refrigerators, freezers, ranges and clothes dryers where equipment use is probably not very sensitive to changes in the total utility bill. Since it is not possible to gauge the magnitude of any takeback effect and because the consumer will benefit when it occurs, this factor is not included in the savings analysis.

There are some generic options for reducing household electricity conservation that do not apply to specific end-uses. These include computerized control systems and "smart meters" that can be used along with spot pricing [4]. Although these options are not explicitly examined in this study, they could prove to be attractive and merit further attention. Such technologies might substitute for or complement various measures that are analyzed here.

B. Cost-effectiveness

In order to analyze the cost-effectiveness of the different technology options, the cost of saved energy (CSE) and cost of conserved peak power over 20 years (CCPP20) are calculated. CSE is given by the annualized extra cost for an option divided by the annual energy savings [5]. At this stage of the analysis, the extra cost corresponds only to the cost of the efficiency measures; utility program costs and other additional costs are not included.

For many options, the CSE is determined two different ways. The first calculation considers the electricity savings and extra first cost relative to the "base" technology option. This is designated the average CSE. The second calculation considers the savings and extra first cost relative to the next most efficient option considered, when options are added in a logical progression. This is called the marginal CSE.

CCPP20 is the net present value of investments required to save a kW of peak demand with a particular option over a 20 year period. Use of 20 years standardizes the capital cost analysis and permits comparison to electricity supply technologies. CCPP20 is evaluated on a marginal basis, i.e., considering the cost and savings relative to the previous efficiency level, when efficiency options added in a logical progression.

Important assumptions that are used in the economic evaluations include a 7% real discount rate and amortization periods equal to the estimated product lifetimes. A 7% discount rate is accepted and used by PG&E when it performs other resource evaluations [6]. Thus, the economic viability of the conservation options is considered from the perspective of utility financing or ownership. This is consistent with the concept of PG&E "building a conservation power plant". The assumed product lifetimes are included in Table 1.

The first cost for the technology options is based on estimated retail prices derived wherever possible from actual production costs. Since this is essentially a technology evaluation, costs associated with programs to encourage the purchase of more efficient products are not included. Of course, administrative, financing, promotion and other costs that PG&E might incur while pursuing a "conservation power plant" must be taken into account, but it is premature to do so at this point in "plant design". It should also be noted that all economic values are given in 1985 dollars.

As mentioned above, the technology assessments generally start from a "base" technology. This type of technology and its associated efficiency level are typical of what is being purchased at the present time based on national shipment and sales data. In most cases, the energy performance of the base technology is consistent with PG&E's residential end-use model. In a few cases (water heating and manual defrost freezers in particular), the energy performance of the base technology is different from that in the end-use model. As discussed further in the specific assessments, it is our judgement that in these instances, the assumptions in the end-use model are unrealistic in relation to what is now occuring and what is expected in the future.

The approach used in judging whether certain technology options are cost-effective is to compare the marginal CSE and CCPP20 to PG&E's accepted marginal energy supply and peak power costs. Table 2 shows the stream of marginal energy and peak power costs used for this purpose. The marginal costs apply to residential consumers (i.e., taking into account T&D costs and losses for the residential service class). They were the accepted marginal costs within PG&E in early 1986 and were used in the 1987 general rate case application [7,8].

The marginal energy costs in Table 2 include a capacity credit based on serving baseload demand (i.e., the average annual capacity cost is distributed over 8760 hours). Conservation options are considered cost-effective on the basis of energy savings whenever the marginal CSE is less than the marginal energy cost. When the marginal CSE for an option falls within the bounds of the 20 year energy price stream, the option is deemed cost-effective during the years when the marginal CSE is less than the marginal energy cost. The energy cost analysis is not done on the basis of net present value over 20 years.

The marginal peak capacity costs shown in Table 1 are annualized values based on some gas turbine additions in some unspecified year along with T&D costs [8]. They are the effective marginal costs during the summer peak demand period, weekdays from 12:00 P.M. - 6:00 P.M. The total marginal capacity cost is given by the net present

Table 2 - <u>Marginal energy and peak capacity costs</u> (1985 $)

Year	Energy[a] ($/kWh)	Peak capacity[b] ($/kW)
1985	0.0773	72.9
1986	0.0715	59.6
1987	0.0643	36.0
1988	0.0626	39.5
1989	0.0622	46.2
1990	0.0597	45.4
1991	0.0646	68.9
1992	0.0666	69.2
1993	0.0681	69.1
1994	0.0732	68.2
1995	0.0772	67.3
1996	0.0804	63.0
1997	0.0812	63.1
1998	0.0846	61.0
1999	0.0877	60.8
2000	0.0926	58.8
2001	0.0952	59.9
2002	0.0978	60.0
2003	0.0980	59.4
2004	0.1018	56.5
2005	0.1013	56.4

[a] Marginal residential electricity costs are derived from the 1987 general rate case application and converted to constant dollars using the GNP deflator series. Personal communication from Bill Smith, Rate Planning Dept., PG&E, Dec. 1985.

[b] Marginal peak capacity costs apply to the summer peak period and are consistent with the marginal costs in the 1987 general rate case application. Personal communication from Paula Rosput, Rate Planning Dept., PG&E, Jan. 1986.

worth of annual costs over 20 years. Assuming a 7% discount rate, the total marginal cost (in 1985 dollars) for the period 1985-2004 is $670/kW. Conservation options that have an incremental CCPP20 less than this value are considered cost-effective on the basis of peak demand savings.

For judging the cost-effectiveness of options that become available in the late 1980s or 1990s, a 20 year stream of marginal peak capacity costs beginning when the measures are available should be used. According the the Rate Planning Department, the marginal capacity cost (in constant dollars) is not expected to change much after the year 2000 [7]. Likewise, the net present value of marginal peak capacity costs for 20 years beginning in 1985 is not much different from the net present value for 20 years beginning in 1990 or 1995. Therefore, it is reasonable to compare the CCPP20 values for conservation options to the total 1985-2004 marginal peak capacity cost even for conservation options that become available somewhat later.

Overall, conservation options that are economical on the basis of either energy savings or peak demand savings are deemed cost-effective and are considered for inclusion in the scenarios associated with the conservation power plant. Options that are expected to become available and economical at some point during the next 20 years are eligible for inclusion when they become so.

C. Notes and References

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TECHNOLOGY ASSESSMENT: REFRIGERATORS AND FREEZERS

A. Introduction and Summary of Results

Refrigerators are one of the most important targets for residential end-use conservation. According to PG&E's end-use model, refrigerators account for about 22% of residential electricity consumption. Freezers are estimated to account for about 6% of residential electricity consumption.

The potential for further energy savings with refrigerators and freezers is very large. Moreover, there is an abundance of relatively inexpensive techniques for achieving these efficiency gains, which are described in this technology assessment.

Considerable progress has been made in improving the efficiency of new refrigerators and freezers in recent years (see Figure 1). According to the test ratings, the typical refrigerator (both single door and two-door models) sold in California in 1983 consumed 1200 kWh/yr, about 30% less than the typical refrigerator sold in 1971 [1]. At the same time, there was a slight increase in the average size of new refrigerators.

The best large, two-door refrigerator-freezer widely available in the U.S. in late 1985 uses only 750 kWh/yr. Some Japanese models appear to be substantially more efficient than this [2], and a very-efficient two-door refrigerator-freezer custom-made in Arcata, CA for use with photovoltaic power systems uses only 250 kWh/yr based on the test ratings [3].

The results of our evaluation show that it is technically and economically feasible to reduce the energy consumption of

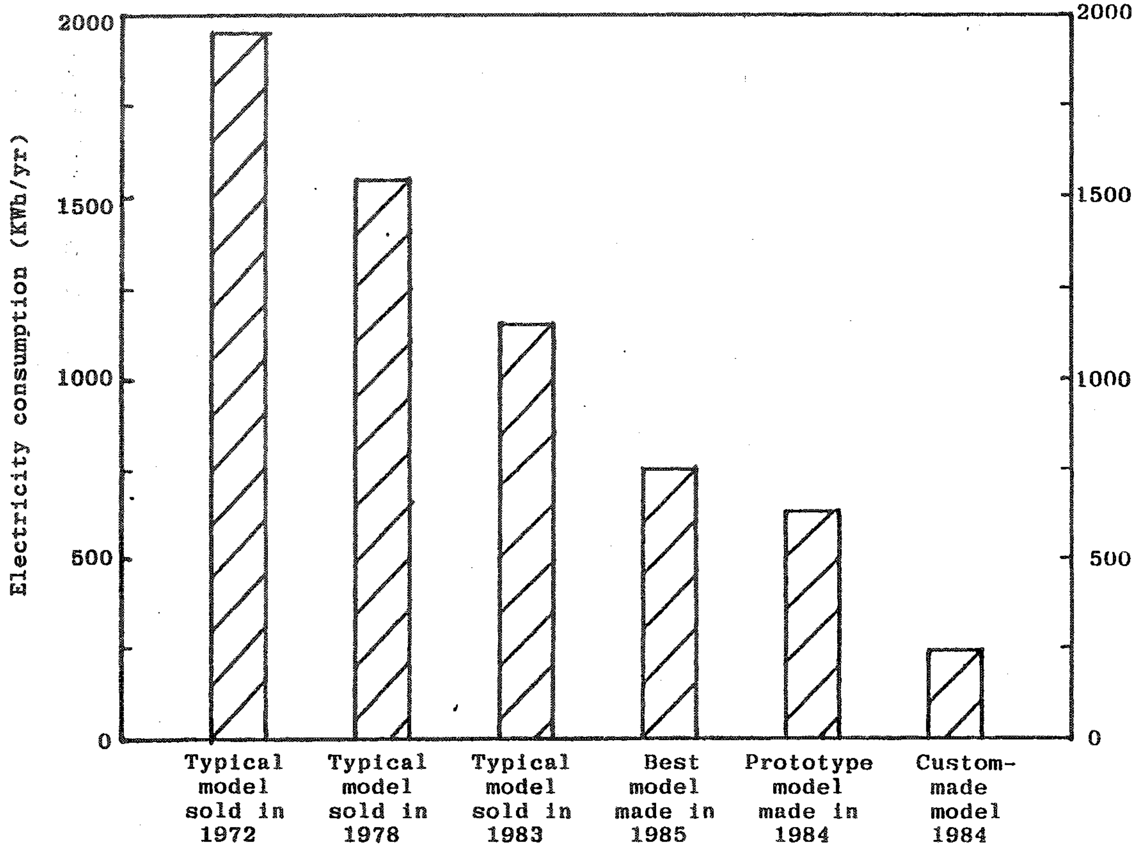

Figure 1 - Progress in the electricity consumption of top mount freezer, automatic defrosting refrigerator-freezers, 16-18 cubic feet manufactured in the U.S.

refrigerators and freezers by as much as 80-90% relative to the energy use of typical American models produced in 1985. This impressive result occurs because many efficiency measures combine in complementary ways. Although most of this savings potential is not yet available in commercial models, we feel that commercial models exhibiting very low energy consumption could become widely available by the early-1990's if manufacturers decide to implement the technologies mentioned in this report.

The results presented are technically robust in the sense that many technical advances "compete" for energy savings. Thus, if some of the assumed measures fail to be as attractive as thought, other measures are available to fill the gap.

B. Methodology

This report examines a wide variety of technologies for improving refrigerator efficiency. It focuses on several of the most promising of these technologies and quantifies the expected costs and savings from incorporating them into the design of refrigerators and freezers. All of these measures are chosen to be technically and commercially feasible for implementation within the next 5-8 years. The measures would result in refrigerators and freezers with greater energy efficiency and comparable or better consumer convenience features.

Analysis of cost-minimizing combinations of these measures is performed in this report. We use our own simplified engineering model (described in a supporting study [4]) to evaluate the energy consumption of the various combinations of measures. This independent simulation is necessary because no attempt has been made in published reports or papers to describe optimal combinations of various conservation measures. However, all of the measures included in this discussion have been fully discussed in the published technical literature. Many of them were carefully reviewed by the appliance industry during proceedings concerning appliance standards.

Some of the conservation measures analyzed in this study involve technically straightforward changes in the design of the product. Others require modest technological advance, or the mass-production of measures that may be more difficult to produce in commercial products than in prototypes. As a result of these distinctions, the report categorizes measures with respect to the degree of technical difficulty or innovation required.

In addition to the engineering analyses of optimal combinations of measures, the report also studies currently existing refrigerators and freezers. It describes the energy performance of mass-produced products in the United States and Japan, as well as the very efficient custom-made model and laboratory prototypes. The performance of these products is compared to the performance predicted by our model in section D below.

1. Definition of Measures and Hypothetical Models

This study utilizes the methods developed by the United States Department of Energy (DOE) in its analysis of appliance efficiency standards [5]. The same techniques were employed by the California Energy Commission (CEC) in its recent evaluation of standards [6], and the methodology has been followed by other consultants to PG&E [7].

This method begins with an hypothetical baseline model that represents a particular class of refrigerators or freezers. The baseline model is chosen to embody the typical size, features, and energy consumption of the class it is intended to represent. However, rather than having rigorously averaged characteristics, it has the technical description (size, component efficiency, etc.) of a particular model. Engineering changes are made to the bseline model, and the cost and energy savings resulting from these changes are calculated. The extra first cost for the changes is estimated on the basis of additional materials and labor costs, along with markups to project cost at the retail level.

The analysis computes the effect of adding discrete energy conservation measures to refrigerators and freezers. A measure involves changing a characteristic of the product, such as increasing the thickness of insulation or improving the efficiency of the compressor. The measures are based on studies that are referenced in the calculations, and these studies generally have been available for several years. Each measure is independent of all other measures, although the energy conserving effect of a measure will depend strongly on the characteristics of the model to which it is applied.

2. Cost of Saved Energy

This study attempts to rank order conservation measures in terms of lowest cost of saved energy and greatest technological feasibility. Beginning with the baseline model, energy conservation measures are added in part by increasing order of cost of saved energy. In principle, this leads to a "supply curve" for conserved energy, in which each succeeding measure is more costly than the previous measure. When some cost threshold is reached, the optimum energy conservation level is found. It should be noted that the energy savings from a given measure are strongly dependent on the order in which measures are applied. For this reason, the primary analysis and rank ordering of measures is done independently of defining certain hypothetical prototypes, where measures are not rank ordered, and are often considered only in packages.

To account for concerns of greater or lesser technological difficulty, measures are further segmented into categories of technological difficulty. All of the simpler measures are considered before more technically demanding measures, regardless of economics. Within each class of technological straightforwardness, measures are again rank ordered according to cost of saved energy.

3. Classes of Products

PG&E in its end-use model divides refrigerators into two categories: manual defrost and automatic defrost. The appliance industry further subdivides these categories. Included in what PG&E calls "automatic defrost" are what the industry calls "partial automatic defrost" units, "top freezer automatic defrost" units, and "side freezer automatic defrost" units. Manual defrost refrigerators account for a mere 7% of the California market according to industry data [1]. Of the "automatic defrost refrigerators", almost 7% are partials, 70% are top freezers, and 23.5% are side freezers. In all, the top mount automatic defrost refrigerator/freezer accounts for 65% of total refrigerator sales in California.

As a consequence, this report focuses most heavily on the top freezer automatic defrost class. A detailed analysis is provided first for this class. Side freezer and manual defrost models are analyzed with less detail.

For freezers, PG&E also distinguishes between automatic defrost and manual defrost freezers in its end-use model. The industry further subdivides manual defrost models into chest freezers and upright freezers. Industry statistics indicate that upright automatic defrost freezers account for only 5% of sales in California, while 40% of sales are chest freezers, and the remaining 55% are manual defrost uprights. Since chest and upright freezers with manual defrost are relatively similar in characteristics and energy use (the typical upright freezer being sold is about 20% larger and consumes 20% more electricity than the typical chest freezer), they are analyzed together in the next section.

C. Technologies for Electricity Conservation

This section presents the principal options considered, the energy demand and savings, the cost-effectiveness for the different categories of refrigerators and freezers. The analyses begin with "baseline" models with efficiencies close to the current average for new sales [1]. Except for the manual defrost refrigerator category, the baseline models are very close in performance to what is assumed for new purchases in 1985 in PG&E's end-use model. (The baseline assumptions for the manual defrost refrigerator are explained further below.)

Efficiency measures are drawn from a variety of sources, including DOE's appliance standards evaluation [5]. Additional analysis of more agressive conservation measures draws heavily on two documents by Arthur D. Little [8]. In addition, some straightforward calculations are made concerning insulation effectiveness.

1. Top Freezer-Automatic Defrost Refrigerators

The assumed volume for this class is 17 cubic feet and the baseline energy use is 1165 kwh/yr [1]. This is similar to the performance assumed by PG&E for new frost-free refrigerators in 1985. Fourteen conservation measures are considered and ranked in cost-effective order as described in the report supporting this assessment [4]. The measures are grouped into packages for simplicity, and the cost and savings of the packages are presented in Table 1.

The first level of efficiency improvements shown in Table 1 is a hypothetical model conforming to the new minimum efficiency standards that go into effect in California in 1992. Although no mass-produced model in the U.S. has yet realized this level of efficiency, it should not be difficult to achieve. The efficiency measures added to the baseline model in order to reach 610 kWh/yr include a moderately improved compressor, more insulation, a

TABLE 1 - OVERVIEW OF TOP-MOUNT REFRIGERATORS-FREEZER TECHNOLOGY OPTIONS

Option	Annual electricity use (kWh/yr)	Peak demand (watts)	Estimated First Cost (1985$)	Total Extra First Cost (1985$)	Average CSE ($/kWh)	Marginal CSE ($/kWh)	Marginal CCPP(20) ($/kW)	Estimated Year Available
Baseline	1165	155	671	---	---	---	---	1985
1992 Standards Model (a)	610	81	731	60	0.010	0.010	810	1987
Low Technology Measures (b)	460	62	807	136	0.018	0.050	3920	1989
Intermediate Technologies (c)	385	51	880	209	0.025	0.089	6740	1991
Advanced Technologies (d)	175	23.5	985	314	0.030	0.047	3770	1993

(a) Includes a moderately improved compressor, more insulation, a more efficient fan and motor, and a double freezer gasket.

(b) Includes a 4.5 EER compressor and a double refrigerator gasket, as well as measures in note (a).

(c) Includes an external fan motor, EER=5.0 compressor, and dual evaporator, in addition to previous measures.

(d) Includes evacuated panel insulation and bottom-mounted condenser, in addition to previous measures.

double freezer gasket, and a more efficient fan and fan motor. These measures are described further below.

Table 1 shows that the estimated extra first cost relative to the baseline model is only $60 while the energy savings is estimated to be 555 kWh/yr. This leads to a cost of saved energy (CSE) of $0.010/kWh, which is extremely cost-effective in light of marginal energy costs. The cost of saved energy is obtained by multiplying the extra first cost by a capital recovery factor and dividing by the annual electricity savings [17]. With a real discount rate of 7% and a 20 year product lifetime, the capital recovery factor for refrigerators and freezers is equal to 0.0944. Thus, the CSE calculation for the 1992 standards model is $60 x 0.0944/555 kwh = $0.010/kwh. Since this is the first option considered after the baseline model, the average and marginal CSE are equal. The estimated cost of conserved peak power (CCPP20) is $810/kW in this case, not nearly as favorable as the CSE. The CCPP20 is derived by dividing the extra first cost by the peak demand savings.

It is estimated that the so-called 1992 standards model could become available in 1987, assuming of course that manufacturers decide to produce it. In any event, full-size automatic defrost models under 700 kWh/yr will become available by the early 1990's, as long as the new standards are in effect.

The next package, labeled as "low technologies" in Table 1, includes measures that are generally available commercially in some refrigerators, or require small changes in existing processes, or the substitution of commercially available parts for those currently used. The lead time for incorporating these measures into new refrigerators is 18 to 24 months. To be conservative, we assume that a model including these features becomes available in 1989.

The added measures are as follows:

- Increased compressor efficiency. Following DOE's study, the compressor efficiency is first increased from 3.18 EER (Energy Efficiency Ratio) to 3.65; further increases in compressor efficiency are then considered. The low technology measures package includes compressor efficiency increases up to an EER of 4.5. This is the most efficient compressor that was available commercially in 1984. The first compressor improvement saves energy at a cost of 0.4 cents/kWh; the second measure has a cost of saved energy of 2.5 cents/kWh (see Reference 4 for details).

- Better Insulation. The measures considered in this package of measures are an increase in insulation from the baseline to the intermediate level of 2 inches for the refrigerator compartment and 2.4 inches for the freezer compartment. A second level is also considered, namely 2.5 inches for the refrigerator compartment and 3 inches for the freezer compartment. All of the insulation measures have a cost of saved energy of less than 1 cent/kWh.

- Better Gasket. Double gaskets are added to the refrigerator and freezer compartment door closures. The freezer double gasket costs 3 cents/kwh of saved energy, while the fresh food compartment double gasket costs 10 cents/kWh.

- <u>More efficient evaporator fan and fan motor</u>. The cold evaporator coil in an automatic defrost refrigerator is isolated from the refrigerated food compartments so that it can be heated up for defrosting. The cold is conveyed from the cold coil to the compartments by a small fan. The efficiency of both the motor and the fan blades is low; this measure involves upgrading these efficiencies in straightforward ways. The measure is very cost-effective with a cost of saved energy less than 2 cents/kWh.

It is seen in Table 1 that the full package of "low technology" measures lowers energy consumption to 460 kWh/yr. This is achieved at an average CSE (i.e., relative to the base model) of 1.8 cents/kWh and a marginal CSE (i.e., relative to the 1992 standards model) of 5.0 cents/kWh. The average CSE is computed in this case based on an annual electricity savings of 705 kWh and an extra first cost of $136. The marginal CSE calculation is based on an annual electricity savings of 150 kWh and an extra first cost of $76. The cost of conserved peak power values are relatively high; thus, the measures can only be justified on the basis of energy savings.

Next, we look at measures of intermediate technological difficulty. These measures are generally not available in the United States at present, but have been demonstrated in prototypes or in foreign products. We estimate lead times for incorporating them into commercial production of 2 to 3 years, and conservatively estimate commercial availability of the package in

1991. Five such measures--of which 3 are potentially cost-effective--are presented in the supporting document [4].

The three cost-effective measures are:

- External fan motor. At present, the energy used by the evaporator fan is dissipated inside the refrigerated volume, increasing the amount of heat to be removed from the refrigerator. This measure removes the fan motor from the refrigerated volume, placing it outside the insulation on the back of the refrigerator. This measure is already employed in some Japanese refrigerators; however, some manufacturers have presented potential reliability concerns with it. Therefore, it is included in the intermediate technology category. The cost of conserved energy is less than 1.5 cents/kWh.

- EER 5 compressor. This measure was included in the 1983 DOE analysis as technically feasible [5]; however, it is not commercially available as a component to manufacturers at present. The improved compressor has been built, tested, and incorporated into prototype models [9]. Also, it appears to be very economical based on the cost of the prototype.

- Dual or Hybrid Evaporator. Current frost free refrigerators use a single evaporator for both the freezer compartment and the refrigerator compartment. The evaporator provides temperatures cold enough for the freezer compartment; and "left-over" cold air chills the refrigerated foods compartment. This method is inefficient because it overcools air for the refrigerator and it dehumidifies the air in the refrigerated food compartment, wasting energy both by condensing moisture out of the air and then by using extra energy for defrosting.

The dual or hybrid evaporator uses a separate cold coil in the refrigerated foods compartment. This coil defrosts naturally during the off cycle when the temperature rises above 32 ^{o}F. This system of two evaporators is currently used in many partial automatic defrost refrigerators and was mass-produced in a frost-free model sold for several years by Amana. However, it is more expensive than other means of achieving a similar level of energy efficiency, and thus was discontinued by Amana.

This measure has benefits in excess of those reflected in the cost analysis for two reasons. First, the higher humidity in the refrigerated foods compartment are an amenity to the homeowner; they help keep the stored food fresher. Second, the DOE test procedure appears to underestimate the energy savings that this technology produces in the real world because the test procedure does not include the introduction of moisture from food or door openings (which produces a dehumidification energy load and a defrosting energy load). Therefore, reductions in this source of energy use are not taken into account by the test procedure.

Using the standard DOE test procedure, this measure, coupled with the EER 5 compressor measure costs 10 cents/kwh saved.

The three cost-effective intermediate technologies are included in Table 1. Energy consumption after the application of these measures is 385 kWh/yr. Overall, the intermediate technology model has an average CSE of 2.5 cents/kWh and a marginal CSE of 8.9 cents/kWh. Thus, considered direcly on a strictly incremental basis, this package of options does not beome cost-effective until around the year 2000 when the marginal electricity cost reaches 9 cents/kWh (see Table 2, Chapter 2). However, since the key measure in this group saves more energy in the field than it does in the DOE test, it is likely to be cost-effective today.

Next, we look at some more highly advanced or speculative technologies.

- Evacuated panel insulation. Currently, conduction of heat through walls and doors is limited by the conductivity of insulating materials such as polyurethane foam. This measure uses a vacuum panel to further suppress heat transfer. The panels resemble a giant thermos bottle. Radiation from one side to the other is cut by the use of reflective surfaces, and the vacuum inside prevents conduction from being a significant method of heat loss. The powder or, alternately, glass balls, in the panels is used for mechanical support. This technology is under development at the Solar Energy Research Institute [10] as well as Arthur D. Little, Inc. It saves energy at a cost of about 3.5 cents/kWh, even after all of the cost-effective measures discussed above have been implemented. It also has the advantage that it allows thinner walls to accomplish greater thermal resistance to heat flow. This measure is estimated to have a five year lead time for implementation in the U.S., although it is reported that the Japanese are already using evacuated panels in some of their more efficient refrigerator models [10].

- Bottom-mounted condenser. This measure adds additional condenser area to that already located behind the refrigerator. By increasing the heat transfer area, the capacity and efficiency of the refrigeration system are increased. Modelling its effects is more problematic than most of the other technologies and for this reason it is listed along with the "advanced technologies".

The high technology measures included in Table 1 are the evacuated panels and the bottom compressor. The refrigerator with these as well as previous measures would have an energy consumption of 176 kWh/yr., an 85% reduction from the baseline technology. The CSE values for these additional measures are very attractive, and it is assumed the advanced model becomes commercially available in 1993.

2. <u>Side Freezer Refrigerator</u>

The analysis of side freezer refrigerators is very similar to the top freezer class. However, only the energy consumption and energy savings resulting from the different packages of measures are determined. The cost-effectiveness of the measures in this case is almost identical to that in the top freezer analysis.

The baseline energy use in this category, 1515 kWh/yr, is close to the average for new models sold in 1985. Energy use drops to 910 kWh/yr for the hypothetical model meeting the 1992 California standard by making some low technology changes.

Incorporating all of the low technology measures reduces refrigerator energy consumption to 615 kWh/yr. Consumption of 525 kWh/yr is achieved with the medium technology package. The high technology package, which for this refrigerator class consists only of evacuated powder panels, cuts energy consumption to 245 kWh/yr.

3. Manual defrost refrigerator.

Although data from manufacturers shows that single door, manual defrost models represent only 7% of new refrigerator sales in California [1], the PG&E end-use model assumes that they are much more prevalent, accounting for about 28% of the refrigerators in the 2005 housing stock. Although the efficiency improvements in recent years for manual defrost refrigerators has not been as dramatic as for auto-defrost models, the cost-effective savings potential is very large.

The baseline model shown in Table 2, about 11 cubic feet in capacity, consumes 565 kWh/yr. This is nearly 20% less than the energy use of the typical new manual defrost refrigerator in 1985 according to PG&E's end-use model, but approximates the current market average [1].

Once again, measures to increase energy efficiency are added to the baseline model and grouped according to technological sophistication. The first option of 445 kWh/yr just satisfies the 1992 California standard. This unit has a somewhat improved compressor and insulation compared to the base model, and it appears to be very cost-effective. Furthermore, some 10-11 cubic foot manual defrost refrigerators commercially available in 1985 use even less energy according to the standardized test ratings [11].

The complete package of low technology options brings down energy consumption to 270 kWh/yr at an estimated marginal CSE of

TABLE 2 - OVERVIEW OF MANUAL DEFROST REFRIGERATOR OPTIONS

Option	Annual electricity use (kWh/yr)	Peak demand (watts)	Estimated First Cost (1985$)	Total Extra First Cost (1985$)	Average CSE ($/kWh)	Marginal CSE ($/kWh)	Marginal CCPP(20) ($/kW)	Estimated Year Available
Baseline	565	77.9	449	---	---	---	---	1985
1992 Standards Model (a)	445	59.6	480	31	0.024	0.024	1690	1985
Low Technology Measures (b)	270	35.8	498	49	0.015	0.010	1160	1989
Advanced Technologies (c)	110	14.2	512	63	0.023	0.039	3130	1993

(a) Includes a moderately improved compressor, more insulation.

(b) Includes a compressor with EER=4.5 and a double gasket, in addition to previous measures.

(c) Includes a compressor with EER=5.0 and evacuated panels, in addition to previous measures.

$0.015/kWh. The advanced technologies option, including a 5.0 EER compressor and evacuated panels, reduces predicted energy consumption to 110 kWh/yr. Once again, this appears to be highly cost-effective based on our estimates of additional production costs.

Some very efficient manual defrost refrigerators have been built and tested in other countries, proving that the efficiencies suggested here are achievable. An 11 cubic foot model made by Laden in Europe is rated at 290 kWh/yr, while a 14 cubic foot model made by Gram in Europe is rated at 315 kWh/yr (based on the European test procedure) [12]. The Japanese have some smaller models rated at 200-250 kWh/yr [12]. Furthermore, a 7 cubic foot prototype built by researchers in Denmark consumes only about 120 kWh/yr [13].

The analysis of freezers follows the methodology used for refrigerators. A baseline model is developed with volume and energy consumption close to the average for current sales. Measures are subsequently added to the base models, grouped according to technological sophistication. The measures employed are essentially identical to those described in the earlier section on refrigerators. The costs are taken for the most part from the 1982 DOE evaluation [5] and from the A.D. Little studies [8].

4. Manual Defrost Freezer

Table 3 displays the cost and performance values for the various hypothetical manual defrost freezers. The baseline model in this category is a 15 cubic foot freezer with an estimated

TABLE 3 - OVERVIEW OF MANUAL DEFROST FREEZER OPTIONS

Option	Annual electricity use (kWh/yr)	Peak demand (watts)	Estimated First Cost (1985$)	Total Extra First Cost (1985$)	Average CSE ($/kWh)	Marginal CSE ($/kWh)	Marginal CCPP(20) ($/kW)	Estimated Year Available
Baseline	715	93.7	445	---	---	---	---	1985
1992 Standards Model (a)	510	67.1	461	16	0.008	0.008	615	1985
Low Technology Measures (b)	300	39.6	574	129	0.030	0.051	4100	1989
Intermediate Technologies (c)	245	32.1	601	156	0.031	0.045	2530	1991
Advanced Technologies (d)	135	17.6	675	230	0.037	0.063	5080	1993

(a) Includes a moderately improved compressor and better insulation.

(b) Includes more insulation and a double gasket.

(c) Includes a compressor with EER=4.5, in addition to previous measures.

(d) Includes a compressor with EER=5.0 and evacuated panels, in addition to previous measures.

energy consumption of 715 kWh/yr, close to the 1985 market average. The second option is a model that is close to the 1992 California standard, averaging together the requirements for chest and upright manual defrost freezers. Chest freezers rated at around 500 kWh/yr are already manufactured and commercially available in the U.S. [11].

In the low technology package, insulation is increased from 2.0 inches to 3.5 inches throughout, and a double gasket is added. These two measures cut energy consumption to 300 kWh/yr at a marginal CSE of 5.1 cents/kWh. The intermediate package of measures includes an upgrade in compressor efficiency to 4.5 EER. This single measure reduces energy use to 245 kWh/yr at a marginal CSE of 4.5 cents/kWh.

The advanced technology package, which includes a further upgrade in compressor efficiency and the addition of evacuated panels, cuts predicted energy use to 135 kWh/yr. Based on our first cost estimates, this package is also cost-effective, with a marginal CSE of 6.3 cents/kWh.

5. Automatic Defrost Freezer

The analysis for automatic defrost freezers parallels that for manual defrost freezers with the inclusion of two additional measures targeted at the defrost system. Table 4 shows the results. The baseline model has an energy consumption of 1150 kWh/yr, slightly better than the current market average. The low technology package of measures, involving better insulation and a better gasket, reduces consumption to 680 kWh/yr. The intermediate technology package contains a 4.5 EER compressor, a

TABLE 4 - OVERVIEW OF AUTOMATIC DEFROST FREEZER OPTIONS

Option	Annual electricity use (kWh/yr)	Peak demand (watts)	Estimated First Cost (1985$)	Total Extra First Cost (1985$)	Average CSE ($/kWh)	Marginal CSE ($/kWh)	Marginal CCPP(20) ($/kW)	Estimated Year Available
Baseline	1150	150.9	656	---	---	---	---	1985
Low Technology Measures (a)	680	89.3	769	113	0.023	0.023	1830	1989
Intermediate Technologies (b)	420	55.1	807	151	0.020	0.014	1120	1991
Advanced Technologies (c)	235	30.6	880	224	0.023	0.037	3000	1993

(a) Includes a moderately improved compressor and a double gasket.

(b) Includes a compressor with EER=4.5, more efficient fan and motor, in addition to previous measures.

(c) Includes a compressor with EER=5.0 and evacuated panel insulation, in addition to previous measures.

more efficient evaporator fan and fan motor and the removal of the motor from the refrigerated space. This package reduces consumption to 420 kWh/yr. The advanced technology package further cuts consumption to 235 kWh/yr--an 80% reduction from the base case. All of the options have marginal CSE values of less than $0.04/kWh.

6. Other Measures Potentially Available

This study focuses on measures for which there is published data on technical specifications, performance, and cost. A number of other advanced conservation measures may become available and may be even more cost-effective than those evaluated above. They were omitted from this analysis due to either greater uncertainties surrounding cost or performances, or our inability to model their effects.

Some of these measures are:

- Improved Conductivity Insulation.
  Japanese refrigerator manufacturers employ a special polyurethane foam insulation material that has a smaller and more uniform cell size and lower conductivity [14]. This feature could have several benefits comparable to those described above. They include the possibility of using thinner walls to achieve the same efficiency, or potentially the ability to use foam insulation to match the performance of the evacuated panels. This measure is not evaluated due to our lack of data on the special foam's conductivity.

- Redesigned Evaporator.
  Unpublished studies by manufacturers have suggested that a redesigned evaporator could have greatly improved heat transfer characteristics. This would raise the

equivalent efficiency of the motor/compressor. However, the studies are not available, so neither performance nor cost can be predicted.

- <u>More Efficient Motor-Compressor</u>.
  The analysis above describes motor-compressor efficiencies that are limited to EER 5. This level of performance was achieved in a U.S. prototype using a 75% efficient motor [9]. It may be possible, however, to increase motor efficiency well beyond 75% in a practical manner. Energy savings would be greater than proportional to the efficiency improvement, because a more-efficient motor produces less waste heat both in the refrigerant circuit and near the cold storage volume. The extent and cost of these improvements could not be quantified, however.

- <u>Use of Different Refrigerants to Improve EER</u>.
  Initial work has suggested that refrigerant mixtures may reduce energy consumption by about 10% [15]. However, this technology is still in the laboratory research stage, and its effects cannot be evaluated with nearly as much confidence as the other measures.

- <u>Two Motors and Two Compressors</u>.
  Several advanced models or prototypes feature separate motor/compressors, evaporators, and controls for the freezer compartment and the refrigerator. The Sun Frost 250 kWh/yr custom-made model has separate refrigeration systems, for example. Its effect is to improve the EER of the refrigerated foods section, as well as to provide the amenity for greater control of temperature. Savings have been estimated at 30% [3]. We found it difficult to quantify precisely the costs and benefits of this measure, so it is not evaluated.

D. Comparison of Predicted Results with Measured Low Energy Refrigerators

There are a number of commercial refrigerators or prototypes that have been designed or modelled whose performance can be compared with the predictions presented above. Data concerning the correspondence of the design features of these products to those analyzed here are fragmentary; however, there is good agreement between the measured energy consumption of these refrigerators and the predicted performance in this study.

We first look at mass-produced American top-freezer refrigerators. The California Energy Commission compiled a list of the 11 most efficient models available in Spring of 1985. These models are generally between fifteen and twenty cubic feet in volume. Although detailed design information on these products is not generally available, they appear to have characteristics associated with an energy consumption of 800-1000 kWh/yr according to our model. This is consistent with the DOE test ratings for these products.

The most efficient U.S. refrigerator on the market in 1985 is the Whirlpool ET17HK1M. This model features a compressor with an EER of 4.5, employs 2-1/2 inches of wall insulation and 1-1/2 inches of door insulation, and uses an improved evaporator fan motor. However, it lacks a double gasket and uses a conventional evaporator fan. The simulation model predicts energy consumption on the order of 700 kwh/yr; actual energy use in the DOE test is 750 kWh/yr, well within the tolerance of our knowledge of the product's specifications.

Some of the mass-produced top-freezer refrigerators in Japan attain efficiency levels comparable to those of the 1992 California standard [2]. For the size used in the cost of saved energy calculations, 17 cu. ft., this is equivalent to a performance of about 400 to 600 kWh/yr, depending on what one believes about the differences between the Japanese and American test procedures. The lower end of the range represents extrapolations of the performance of the more popular smaller Japanese models, which appear to be more efficient; whereas the higher end of the range involves looking at the larger (around 15-19 cu. ft.) Japanese refrigerators. The Japanese products apparently employ many of the measures in the low and intermediate technology packages in Table 1, although they tend to use less insulation than that assumed here. The Japanese test ratings for these models are similar to the energy consumption levels predicted by the model employed here.

The most efficient refrigerator currently manufactured in the U.S., the Sun-Frost, is made in quantities of dozens per year. This 16-cubic foot top-freezer type refrigerator consumes about 250 kwh/yr using the DOE test and about 200 kWh/yr in one household with <u>in situ</u> measurement. Although the Sun Frost does not use the evacuated panels, it employs very thick conventional insulation with a conductance that approaches that of the panels. It also uses a partial automatic defrost rather than full automatic defrost, which eliminates the effect of the fan motor and the defrost energy and its load. If we recalculate the intermediate technology package in Table 1 without the defrost heaters or the fan energy, the model predicts an energy consumption of 280 kWh/yr. If we then add the effects of thicker insulation, we obtain a range of predictions that are very close to the measured results for the Sun Frost refrigerator.

This discussion shows that the ultra-low energy consumption levels predicted by our model are actually achievable. It also illustrates that the range of performance levels currently available is consistent with the approximate performance levels predicted by the model.

More careful calibration of the simulation model would be useful. Such a task would involve measuring the five energy descriptive parameters of specific models such as the Sun Frost or a particular Japanese refrigerator and comparing predicted performance to measured energy performance.

E. Peak Load Considerations

Refrigerators present the utility with a load that is nearly constant throughout the day and the year. There are small seasonal variations relating to the lower effective EER of the refrigerator compressor when the room temperature is higher, coupled with the increase in conduction loads under the same conditions. Also, food loading and door openings create some daily variations. A study done at Lawrence Berkeley Laboratory estimated that the summer peak load is roughly 1.15 times the annual average load. The CEC estimates a peak load factor of 1.17, in good agreement with the LBL result. The corresponding value for freezers is 1.15 according to the CEC. These values are used to estimate the peak power demand for the different options presented in Tables 1-4.

F. Research and Development Recommendations

PG&E is already actively supporting the development and commercialization of energy-efficient refrigerators and freezers. One Japanese model that is supposed to be relatively efficient has been obtained and its performance is currently being monitored. Also, a leading European appliance research center has been funded to develop a new, highly efficient top mount refrigerator-freezer [16]. Research of this sort to advance the state-of-the-art in an area like refrigerators is extremely useful, and it should contribute to an effort to deploy a "conservation power plant".

The relationship between energy performance based on the standard U.S. test procedure and energy performance in the home is a critical issue that is of interest to appliance and conservation specialists throughout the nation. Understanding this relationship is essential for assessing the true value of more efficient refrigerators and freezers, and for assessing programs that encourage their purchase or manufacture.

It would be useful, therefore, for PG&E to monitor the energy consumption of refrigerators and freezers in homes over an extended period of time. At the same time, information on brand, model, age, number of users, and test rating should be collected. We suggest performing field monitoring in a substantial number of households, including some households that have newer, more efficient models. It might be possible to carry out this activity as part of a comprehensive residential survey.

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TECHNOLOGY ASSESSMENT: WATER HEATERS

A. Introduction

Water heating is the fifth largest residential end-use of electricity in the PG&E service territory. For households with electric water heating, the unit energy consumption (UEC) is about 3300 kWh/yr, but only about 9% of the households served by PG&E heat water with electricity. Nevertheless, there is substantial potential for conserving electricity and peak power in this end-use.

PG&E's end-use model has not been recently updated for electrical water heating. The end-use model assumes that almost all new electric water heaters purchased starting in 1982 are heat pumps, an unrealistic assumption. Because of this, we created our own baseline forecast from which to measure the savings potential. Making a baseline forecast also permits the use of a set of consistent assumptions regarding hot water consumption patterns. To simplify the assumptions, we split the housing stock into single family and "other", where "other" consists of mobile homes and multi-family units. Single family homes account for 74% of electric water heaters in 1985. The remainder are split almost equally between multi-family and mobile homes.

Three principal factors determine the electricity consumption of a water heater: 1) the volume of the hot water consumed, 2) the efficiency at which the electricity is converted to useful heat, and 3) the standby losses. Other factors, such as water and ambient temperatures, can also play a significant role. The Department of Energy (DOE) test procedure calculates an "Energy Factor (EF)" for water heaters, based on a fixed level of water consumption. The energy factor represents a combination of the conversion efficiency and standby losses assuming 64 gallons/day of hot water are supplied. Most of the data presented here are in terms of DOE energy factors.

Recently, new technologies have been developed that recover waste heat from other household activities, such as air conditioners, ventilation systems, showers, and refrigerators. Electricity can be saved if the water heater can use this waste heat instead of electricity. Standard procedures for estimating the waste heat contributions have not yet been developed. As a result, the values used in this report are our estimates based on limited field tests and calculations.

Electricity consumption for hot water heating can be reduced by addressing the factors listed above (i.e., by lowering hot water consumption, increasing the conversion efficiency, lowering standby losses, or by recovering heat from other sources). The electricity savings resulting from a particular measure are closely tied to the status of all three factors. Improving the conversion efficiency of a water heater, for example, reduces the value of additional measures for cutting hot water consumption or standby losses. This situation greatly complicates the calculations of energy savings because the energy savings for a given measure depend on the measures already implemented. The problem is addressed in this analysis by considering measures for increasing energy factor given different levels of hot water consumption, and measures for reducing hot water consumption given different energy factor levels.

B. Baseline Assumptions

We estimate that single family homes with electric water heaters use 4400 kWh/year in 1985. This estimate is based on a national compilation of data regarding the electricity consumption of water heaters [1]. This data base shows that the average electricity consumption for several hundred water heaters was 5326 kWh/year, with an average hot water consumption per occupant of 16 gallons/day. We adjusted this average electricity consumption value to reflect the average number of occupants in PG&E single family homes as determined by the PG&E Residential Appliance Saturation Survey (RASS) [2], that is, 50 gallons/day for 3.06 persons, resulting in an estimated electricity use of 4400 kWh/year. These usage levels correspond to an EF of 0.81, almost exactly the shipment-weighted energy factor for electric water heaters during the 1970s [3].

PG&E in its end-use model estimates a UEC for single family homes of only 3274 kWh/year in 1985. This low UEC estimate appears to be due to the assumption that heat pumps have been used in almost every new electric water heater installation since 1982 and accounted for nearly 38% of electric water heaters in 1985. Heat pump water heaters are only now appearing in the California market, however, and only a small fraction of the new homes with electric water heating have installed them in recent years. Thus, we depart from the UEC values in PG&E's model.

In order to analyze hot water conserving measures, we constructed a reasonable breakdown of hot water use by activity in single family homes. The breakdown is based on analysis at LBL [4], measurements by Consumer Reports, and other sources. Table 1 shows our estimates of the principal hot water end-uses in both single family and other households. In single family homes, clothes washers and dishwashers are expected to account for nearly 50% of total hot water demand. In other households, this fraction is expected to be less than 30%.

Table 1 - 1985 hot water use assumptions for single family and other homes

	Single family	Other
Hot water demand (gal/day)		
showers	20	16
clothes washers	13	3.5
dishwasher	10	5
sink/misc.	7	6
Total	50	31
Energy factor rating	0.81	0.74
UEC (kWh/yr)	4400	2970

Hot water conservation measures have already received considerable attention in PG&E's conservation programs and by homeowners in general. According to the 1983 survey, 40% of households in the service area claim they have installed low-flow showerheads and 25% say they have installed insulation blankets [2]. Hot water use will continue to decline as water-saving clothes washers and dishwashers gradually replace less-efficient units. In addition, greater consumer awareness and improved detergents will lead to increased use of cold-water settings on clothes washers, further reducing hot water consumption. These actions are likely to go forward even without new, aggressive utility programs. Therefore, we assume in our baseline scenario that hot water consumption gradually declines over time.

Some of the options described in this chapter can further reduce hot water demand and electricity use. However, measures that could be perceived as lowering amenities or standards of living have been intentionally excluded from our analysis. For this reason, low-flow showerheads are not included as an option (even though some low-flow showerheads do provide comfortable showers).

For other housing, hot water use is assumed to equal 31 gallons/day in 1985, corresponding to an electricity demand of 2975 kWh/yr per household. In reality, little information exists on either hot water consumption or electricity consumption for water heating in multi-family housing or mobile homes. Our estimates are based on occupancy differences between single family and "other" housing derived from PG&E's Residential Appliance Saturation Survey [2].

C. Options to Improve Energy Factor

Table 2 summarizes the options for increasing the energy factor of hot water heaters and the corresponding savings and cost-effectiveness assuming a hot water demand of 50 gal/day. The results for other water consumption levels are discussed below.

1. Thermal Traps and Insulating Blankets

Even when there is no demand for hot water, water can rise through the hot and cold water feed lines that extend from the top of a storage tank due to natural buoyancy. In this manner, heat is lost to the surrounding air. This convection loop is a very effective thermal

Table 2. Overview of Water Heater Conservation Options[a]

Option	Energy Factor	Annual elec. use (kWh)	Peak demand (kW)	Est. first cost (1985$)	Extra first cost (1985$)	Avg. CSE ($/kWh)	Marginal CSE ($/kWh)	CCPP(20) ($/kW)	Est. year avail.
Baseline	0.81	4400	542	300	--	--	--	--	1985
Thermal traps & ins. blanket	0.9	3960	488	335	35	0.010	0.010	840	1985
Avg. HPWH	1.6	2230	275	1050	715	0.041	0.049	4350	1985
Best 1985 HPWH	2.2	1620	200	1350	300	0.045	0.059	5180	1985
Advanced HPWH	2.6	1370	169	1500	150	0.047	0.072	6270	1987
Exhaust heat recovery HPWH	2.0	1280	137[b]	1750	250	0.056	0.332	2360	1987
De-superheater (summer)[c]	--	2970	0	700	700	0.085	0.085	1860	1985
De-superheater (all year)[d]	--	2640	0	700	700	0.063	0.063	1860	1985

[a] Based on a hot water demand of 50 gal/day.

[b] Some proposed designs reverse air flow during the summer and therefore cool incoming air. This cooling benefit has not been included, even though it could significantly increase peak demand savings.

[c] Estimate assumes that the de-superheater contributes three months of hot water and that the original unit had an EF = 0.90. The cost for the de-superheater does not include the cost for the hot water heater itself.

[d] Estimate assumes that the de-superheater operates with a heat pump providing savings during the winter as well as during the three summer months. The cost for the de-superheater does not include the cost for the hot water heater itself.

short circuit. Small one-way valves, also known as thermal traps, will eliminate the convective loop. Thermal traps are simple, reliable, and readily available. The valves are installed in place of standard connection nipples. Installation requires no training or special equipment (although they don't work if installed backwards!).

Curiously, the California water heater standards do not require thermal traps, and only a small fraction of electric resistance water heaters that are sold come equipped with them. Regarding electricity savings, LBL found five studies of thermal traps with savings ranging from 280-480 kWh/yr [1]. Sears reports 215-330 kWh/yr savings in its 1984 catalog. To be conservative, a savings of 7% or 310 kWh/yr is assumed when thermal traps are installed on an electric resistance water heater.

Installing an insulation blanket around the water tank is another simple and effective conservation measure. This option includes wrapping an existing tank with an insulation blanket if none is already present. The electricity savings will depend on the conditions of the original tank. In California, most electric water heaters are already relatively well-insulated as a result of the appliance standards. We conservatively estimate that the addition of a blanket will save about about 3% or 130 kWh/yr on the average starting with a baseline demand of 4400 kWh/yr.

Thus, the combination of thermal traps and insulating blanket should save 440 kWh/yr on the average. This would raise the EF rating from 0.81 to 0.90.

Thermal traps cost as little $8 if purchased from Sears. If the traps are installed when the water heater is replaced, there will be no cost because they substitute for standard connection nipples. Insulating blankets cost about $15 and take about 15 minutes to install. We assume a total installed cost of $35 for both of these measures. As shown in Table 2, the CSE for these measures is only $0.010/kWh.

2. Heat Pump Water Heaters

Heat pump water heaters (HPWHs) are similar in design to room air conditioners and refrigerators. They transfer heat from the ambient air to water in a tank. HPWHs deliver more heat than the electrical energy they consume; as a result, their steady-state efficiency (or COP) is greater than one. The COP rating does not normally include heat losses through the tank walls and distribution pipes. The "Energy Factor" (EF) includes these losses, and is therefore lower than the COP of the HPWH itself. Typical energy factors for HPWHs are 1.4 - 2.0 (i.e., the useful heat they provide is equal to 140-200% of the energy in the electricity consumed) [1]. Since electric resistance water heaters have energy factors of 0.7 - 0.9, the adoption of HPWHs can reduce electricity use by 50% or more.

HPWHs can be mounted as a retrofit or as an integral unit (with storage tank). They were first introduced around 1980, and are now available from at least 10 companies [5]. They have been extensively tested and are now selling well in at least one location (Hawaii).

Three HPWH options are considered in this analysis:

1) Converting resistance water heaters to today's average HPWH;
2) Using the best HPWH available today;
3) Upgrading to an advanced HPWH.

The most efficient HPWH available in the U.S. in late 1985 is made by the Therma-Stor Products Group of DEC International, a company located in Madison, WI. The DEC unit has an EF of about 2.2 compared to about 1.6 for an average HPWH [3]. The modifications used to achieve this performance level include use of an improved plate condenser, thicker insulation, and thermal traps.

Achieving the efficiency assumed for the advanced HPWH (EF=2.6) will require further improvements, perhaps involving a modified compressor, variable-speed motor drives, or improved heat exchangers. DEC International is already developing an advanced HPWH that is expected to meet this performance target [6]. It is similar in design to their existing efficient models [6].

Variable-speed drive is a more radical innovation that could reduce cycling losses in the compressor by varying the heat output according to the load. Although this innovation has not yet been used in small heat pumps in the U.S., it is already commonly used in heat pumps in Japan [7].

California's building standards virtually require new homes with electric water heating to install HPWHs. Our baseline forecast assumes that all new homes built after 1985 include HPWHs with EF=1.6, while ordinary retrofit HPWHs have an EF of 1.5. Retrofits will be less efficient because of the need to circulate refrigerant a greater distance and because of less-than-optimal tank insulation.

The first cost estimates for HPWHs shown in Table 2 are derived from a number of sources. According to a major review of HPWHs conducted by EPRI, HPWHs typically cost $500-1000 more than an electric resistance water heater [5]. With installation, it is assumed that an average HPWH costs $1050, $750 more than the baseline option. The top-rated DEC International HPWH (a tank-integrated model) has a first cost premium of about $300 compared to an ordinary HPWH-tank combination [6].

The extra first cost for the advanced HPWH is more difficult to estimate. The technologies are available, but an advanced HPWH has not been produced. Some improvements clearly cost more, especially better heat exchangers, compressors, and motors, because more metal, closer tolerances, and more intricate fabrication will be needed. At the same time, economies of scale should occur as HPWHs become more common. We estimate that the additional improvements will cost about $150 at the retail level, based on information from the manufacturer of highly efficient HPWHs [6].

The lifetime of HPWHs is uncertain. One study examined the condition of prototype units after 25 months of operation, concluding that the units should last at least ten years [8]. Tank corrosion, not heat pump performance, appears to be the limiting factor. It is assumed that HPWHs last as long as electric resistance water heaters (13 years).

Table 2 shows that based on a hot water demand of 50 gal/day, the average and marginal CSE values for an "average" HPWH are $0.041/kWh and $0.049/kWh, respectively. Today's top-rated model also appears to be cost-effective with a marginal CSE of $0.059/kWh. The advanced HPWH is estimated to have a marginal CSE of $0.072/kWh and is therefore not cost-effective until the 1990s. These CSE values increase by 25% if hot water consumption is 40 gal/day. For multi-family and mobile homes with an estimated hot water consumption of around 30 gal/day, the CSE increases by 67% from the values in Table 2. Consequently, even the average HPWh is not economical at the present time in such instances from the perspective of PG&E's marginal costs. Producing smaller, less costly HPWHs could possibly lead to cost-effectiveness in low-use situations.

For calculating peak demand, a peak-to-average demand factor of 1.08 is used. This value may be somewhat lower with a HPWH because the heat pump will operate most efficiently during the peak period (summer afternoon). In contrast, a resistance water heater's efficiency will only change slightly over time. This means the CCPP(20) values shown in Table 2 may be somewhat overstated. However, lowering them moderately would not lead to competitiveness on the basis of peak demand savings.

3. Exhaust Heat Recovery From Ventilation Systems

New homes are increasingly being equipped with air-to-air heat exchangers to insure sufficient ventilation. Unfortunately, the units have proven to be of questionable economic value and are sometimes unreliable [9]. An alternative technology has been developed in Sweden to reclaim the heat in the exhaust air stream using a heat pump and transfer it to the water tank. At least one American and one Canadian manufacturer are testing prototypes that they plan to market soon in North America [10].

Exhaust heat recovery with a heat pump can be simpler than an air-to-air heat exchanger if only one ventilation air duct is used. For example, stale air can be exhausted through a single ventilation duct during the winter with fresh air drawn in through the building envelope (or small ports above the windows). During the summer, the flow can be reversed. Hot, outdoor air drawn through the duct is cooled and dehumidified as heat is extracted by the HPWH. The arrangement provides significant peak power savings (as long as there are hot water demands during the cooling period).

It might be assumed that a HPWH will operate very efficiently when extracting heat from exhaust air (due to the relatively high air temperature). However, one company that is field testing systems in the U.S. has found that this is not necessarily the case [6]. Extracting heat from a limited quantity of ventilation air lowers its temperature substantially, both in the winter and summer. This reduces the water heating efficiency.

In Table 2, it is estimated that the exhaust heat recovery HPWH operates with an EF rating of 2.0, and that there is a 500 kWh/yr credit for reducing electricity consumption for air conditioning [6]. Also, it is assumed that there is essentially no peak electricity demand for water heating during the summer because of the air conditioning benefit (i.e., the heat pump is viewed as an air conditioner during the summer, with hot water as a byproduct).

An exhaust heat recovery HPWH must be installed in conjunction with a ventilation system. One company developing this equipment in the U.S. estimates that the entire system will cost $1500-2000 (including installation) [6]. As seen in Table 2, the exhaust heat recovery HPWH has a high marginal CSE relative to the advanced HPWH option since there is only minimal added energy savings. Of course, the system is providing ventilation as well as hot water and air conditioning. This option does show a reasonable average CSE of $0.056/kWh when considered relative to the baseline option.

4. De-Superheaters On Central Air Conditioners and Heat Pumps

At one stage in the thermodynamic cycle of air conditioners and heat pumps, the refrigerant leaves the compressor at a temperature of over 140 degrees. At this point, the hot "superheated" refrigerant must be cooled. In air conditioners, the so-called superheat is exhausted to the outdoors. Heat pumps when operating in the heating mode release this superheat indoors. This is thermodynamically wasteful because the quality (or temperature) of the heat is higher than what is needed for space heating.

A de-superheater unit consists primarily of a heat exchanger to transfer heat from the refrigerant line in a central air conditioning system or heat pump to the water heater. During the air conditioning season, a de-superheater can provide a large fraction of the hot water needs for a typical home [11]. A de-superheater will be most effective during peak load hours because this is when cooling is most intensive. Also, a de-superheater will improve the efficiency of an air conditioner, although the magnitude of this effect is difficult to estimate. If a de-superheater is used with a heat pump during the heating season, it will lower the space heating capacity, a disadvantage. But it will heat water at high efficiency and reduce cycling losses thereby improving the heat pump's seasonal performance.

De-superheaters have been on the market for at least five years. They are becoming increasingly popular in the sun belt (e.g., Florida, Texas, and Arizona). Some utilities such as Florida Power and Light Co. are offering rebates to customers who install them (principally because of the peak demand savings). Some central air conditioner systems can be factory-equipped with de-superheaters.

The potential for de-superheaters in Northern California is unclear. First of all, central air conditioning and heat pumps are only found in 21% of households in the service area as of 1983. Furthermore, if technologies such as indirect evaporative coolers or ventilation cooling are adopted (see Chapter 6), there will be no opportunity for using a de-superheater.

In order to evaluate cost-effectiveness, it is assumed that a de-superheater provides all hot water needs during the three summer months. The cooling season is longer in most Northern California regions, but there will probably be intervals when the de-superheater does not provide sufficient heat. Three months of water heating displacement corresponds to a savings of 990 kWh/yr starting from a baseline demand of 3960 kWh/yr (i.e., an electric resistance water heater with EF=0.90).

One review of de-superheaters found installed costs of $400-800 in Florida and Texas [11]. Assuming a first cost of $700 and a 13 year lifetime, the CSE is equal to $0.085/kWh (see Table 2). If a de-superheater is used with an heat pump in the heating mode, the annual savings should increase. Table 2 shows that if the savings increases to 1320 kWh/yr (equivalent to an overall savings of one third), the CSE is reduced to $0.063/kWh.

D. Water Demand Reduction Options

The measures for reducing hot water demand are considered assuming two water heater energy factor levels; EF=0.90 and EF=1.60. This implies use of either a relatively efficient electric resistance water heater or an average HPWH. The electricity savings potential and cost-effectiveness results are shown in Table 3. All of the options in Table 3 are considered independently (i.e., the average and marginal CSE values are equal).

1. Low-water washing machines

Front-loading washing machines use less hot water per pound of laundry than comparable top-loading units. This measure involves replacing top-loading washing machines with front-loading models. Front-loading models are available today but are not especially popular in the US (only a few models were offered in 1985). In Europe, however, front-loading models are by far the most popular [12]. European washers appear to be more efficient than American models, although direct comparison is difficult because the former heat water directly in the washing machine. Front-loading washing machines are also supposed to be quieter, take up less space, and use less detergent than top-loaders [13].

According to the test ratings used to develop the Energy Guide labels for clothes washers, the front-loading models currently produced in the U.S. consume 450 kWh/yr compared to 620-1580 kWh/yr for top-loading clothes washers [14]. Most of this electricity use is for hot water heating rather than directly running the washer. We estimate that a front-loading washing machine will typically use about 50% less hot water than a top-loader, saving about 6 gal/day of hot water. This corresponds to an electricity savings of about 480 kWh/yr with an EF=0.90 water heater and a savings of about 270 kWh/yr with an EF=1.60 water heater.

Based on prices from Montgomery-Ward, front-loading washing machines cost about $150 more than comparable top loading models [15].

Table 3 - Overview of hot water conservation options

A. Assuming a water heater energy factor of EF=0.90

Option	Annual elect. savings (kWh)	Peak demand savings (kW)	Est. first cost (1985$)	Extra first cost (1985$)	Avg. CSE ($/kWh)	Marginal CSE ($/kWh)	CCPP(20) ($/kW)	Est. year avail.
Front-loading clothes washer	480	0.059	550	150	0.037	0.037	2200	1985
Shower-bath economizer	320	0.036	--	300	0.133	0.133	12,600	1988
Low-temperature dishwashing	400	0.049	--	100	0.030	0.030	2640	1990

B. Assuming a water heater energy factor of EF=1.60

Option	Annual elect. savings (kWh)	Peak demand savings (kW)	Est. first cost (1985$)	Extra first cost (1985$)	Avg. CSE ($/kWh)	Marginal CSE ($/kWh)	CCPP(20) ($/kW)	Est. year available
Front-loading clothes washer	270	0.033	550	150	0.066	0.066	3930	1985
Shower-bath economizer	180	0.022	--	300	0.237	0.237	20,600	1988
Low-temperature dishwashing	225	0.028	--	100	0.053	0.053	4700	1990

However, there appears to be little technical justification for this extra cost, except that a better sealing door and possibly better controls are required. Much of the extra cost may be due to the low level of production. Table 3 shows that even with an extra first cost of $150 and a conservative lifetime of 13 years, the front-loading washer has a CSE of only $0.037-0.066/kWh at the water heater efficiencies considered.

2. Shower-bath economizer

The shower-bath economizer recovers heat from hot water going down the drain by transfering it to incoming cold water. The heat exchanger is installed underneath the drain. The Tennessee Valley Authority (TVA) has thoroughly tested the system in the laboratory as well as in five homes [16]. In addition, it has installed the economizers in thirty sites to observe long-term performance. The laboratory unit worked well at 25 showers/day, even with simulated hair and grit. Some field units clogged but this was apparently due to improper installation.

The economizer is very simple to install during home construction, although all test units have been installed as retrofits. They cannot be installed in homes built on concrete slabs or in second-floor showers. Given the installation restrictions, it is unlikely that the economizer could be widely used in apartments or mobile homes.

The shower-bath economizer typically recovers 40% of the heat available from the waste water, although recovery efficiency varies with flow rates, cold water temperature, and other factors. The energy savings thus compare to that from installing a low-flow showerhead. Electricity savings will also depend on the water heater's energy factor.

Alternatively, the heat in waste water could be recovered through a heat pump. This design requires more plumbing because refrigerant lines have to be run between the heat source and a HPWH. Nevertheless, it may be more reliable than a direct water-to-water heat exchanger. In addition, the user need not adjust shower temperature as the heat exchanger begins operation. One can imagine a network of refrigerant lines linking a HPWH with various grey water sources (shower, washing machine, dishwasher) and the exhaust from a clothes dryer. Depending on the efficiency of these activities, a major fraction of the hot water energy requirements might be met through heat recovery.

The prototype shower-bath economizer costs only $50 uninstalled. Bidded costs for installation averaged $300 in the TVA area. However, the plumbers had not installed the units previously and installation costs should go down with experience. The TVA retrofit installations only required 2-3 hours.

For this analysis, it is assumed that the shower-bath economizer has a total cost of $300 and saves the equivalent of 4 gal/day of hot water. No data are available regarding lifetime although TVA's accelerated testing program should be completed soon. Clogging is likely to be a problem, and extensive maintenance may be needed after a number of years. A 10 year lifetime is assumed in this analysis. Table 3 shows that with these assumptions, the shower-bath economizer has a CSE of $0.13-0.24/kWh, considerably greater than PG&E's marginal electricity supply costs.

3. Low-temperature dishwashing

Including the electricity needed for water heating, dishwashers typically consume 600-1100 kWh/yr [14]. It is reported that the average electricity use of new dishwashers has declined 36% during 1972-84 [17]. Most of the improved energy efficiency in dishwashers has been a result of improved mechanical operation and reductions in hot water consumption.

Energy consumption could be further reduced through lowering the water temperature. At the present time, a temperature of approximately 140°F is needed to clean dishes properly. It may be possible to develop detergents that clean adequately at lower temperatures. Each 10°F reduction in water temperature should lower overall energy consumption by about 5% through reduced thermal energy delivery for fixed-volume demands as well as through reduced standby losses from the water tank [18]. Additional savings could result if water is heated using a HPWH.

Improved detergents have been developed enabling clothes washing at lower temperatures. Also, there there has been considerable progress on commercial (i.e., restaurant and institutional) dishwashing detergents that permit reducing temperatures from 180 to 140 degrees for commercial applications. These advances indicate, but do not prove, that detergents can be developed permiting lower water temperatures in residential dishwashers.

The dishwasher's hot water demand typically sets the minimum storage temperature for water. If this temperature can be lowered, tank standby losses will drop. In addition, heat pump performance will improve.

Another possibility is is to equip the dishwasher with an independent booster heater, a feature already available on some dishwashers. This will save energy as long as the tank temperature is lowered.

A high-efficiency prototype dishwasher known as the Ecotech has been developed [19]. The manufacturer claims that the dishwasher cleans a 6-place setting in 90 seconds using water temperatures 20-25% lower than a conventional unit. The Ecotech operates using a jet spray created by water pressure. Although no independent testing has been reported, this technology appears promising.

For the sake of analysis, it is assumed that a breakthrough is made by 1990 enabling a 20 F reduction in water heater temperature, and that this provides the equivalent of a 5 gal/day reduction in hot water consumption. In addition, it is assumed that the associated cost is $100, although the actual cost may be much lower or even negligible. A lifetime equal to that assumed for water heaters and dishwashers -- 13 years -- is used. Table 3 shows that such an improvement would be cost-effective on the basis of its CSE as long as the extra first cost does not exceed $100.

E. Research and Development Recommendations

R&D needs to be conducted on a variety of waste heat recovery options. Potential waste heat sources include an air conditioner, ventilation air, clothes dryer, refrigerator, and freezer. Waste hot water sources include the shower, dishwasher, and clothes washer. The challenge is to capture the waste heat and transfer it to the water heater. Heat exchange with soapy, dirty water and lint-filled air require new heat exchanger designs that are self-cleaning and resist build-up of deposits. Transferring the heat to the water heater may be accomplished by moving water, air, or refrigerant. Each method has its advantages, but no careful study has been conducted.

It is difficult to predict which options will be economical for heat recovery. Recovering waste heat from a refrigerator might be economical at the current level of refrigerator efficiency, but this may not be the case with new energy-efficient models. Some appliances could be easily modified during production to permit heat recovery. For example, some central air conditioners are factory equipped with de-superheaters. It may be possible to develop similar options for other appliances.

The energy factor of HPWHs can still be improved, and less expensive techniques to achieve high EFs are needed. Such developments would encourage a greater number of HPWH retrofits, especially in mobile homes or homes already using a small amount of hot water. Areas deserving further investigation include improved heat exchangers, improved compressors, variable speed drives and controls to best exploit variable speed capability. Even the heat pump's location should be studied. Drawing warm air from the attic, for example, may prove to be effective in certain situations since the attic is typically warmer than ambient air (even with a well-insulated attic floor).

A HPWH can double as an air conditioner in the summer. This reduces the cost of the heat pump, but imposes new constraints upon its operation. The two end-uses must be coordinated for maximum efficiency. New controls and logic, not to mention a larger storage tank, may be needed to ensure efficient operation. Also, it may be necessary to dump heat outdoors as well as to the water tank if the air conditioning load exceeds water heating requirements. Prototype air conditioning-water heating systems need to developed and field tested.

To our knowledge, there has been insufficient research and development of new, low-temperature detergents for dishwashers. Low-temperature, environmentally safe detergents would reduce dishwasher energy use while allowing lower hot water storage temperatures and improved HPWH performance. Other techniques for achieving these objectives (e.g., the prototype "Ecotech" dishwasher) should also be investigated.

Cycling of electric water heaters is now well-established for utility load management. But current cycling controls only respond to a signal from the utility in order to turn off a water heater for a pre-determined period of time. It may be possible to develop new "smart" controls and logic that, for example, sense demand conditions and water temperature as well as receive signals from the utility. This could lead to greater peak load reductions with less inconvenience to the consumer.

A final area that needs to be researched is hot water use and conservation potential in multi-family and mobile homes. Besides obtaining better data on hot water demand and overall electricity consumption, the development of smaller HPWHs and integrated appliances could be especially useful.

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TECHNOLOGY ASSESSMENT: LIGHTING

A. Current lighting use

A market research study made by PG&E in the early 1970's estimated 1200 kWh per household per year for lighting in the residential sector [1]. Lighting experts at General Electric Co. estimated that the typical household in the U.S. consumed 1015 kWh/yr for lighting in 1981, down from 1170 kWh/yr in 1971 [2]. This reduction in lighting electricity consumption is logical given rising electricity rates and declining average household size.

For this study, we estimate an average of 1000 kWh per household per year for lighting as a base case. This is consistent with PG&E's end-use model, which assumes that "miscellaneous consumption" is about 1540 kWh/yr. PG&E planners estimate that about two-thirds of miscellaneous consumption is for lighting [3]. Lighting electricity consumption per household is kept constant over time in the base case to be consistent with the PG&E model.

Load curves which give the daily distribution of lighting electricity consumption in the PG&E service territory are available, but are some 30 years old [4]. These curves show that, as expected, the peak in domestic lighting use begins around 6PM and continues until about midnight. According to the CEC, the peak-to-average load factor during the summer peak load period (2-6 PM) is 0.56 [5]. This yields an average contribution to peak demand of only 64 Watts per household. Since this value is relatively low, the emphasis in this assessment is on saving kWhs and the cost-effectiveness of doing so.

General Electric Co. estimated during the 1970's that 93% of the residential lighting market is comprised of incandescent bulbs and the remainder is fluorescent lights [6]. One-way type incandescents in ceiling applications dominate. As for wattages, 60W bulbs are the most common; almost two-thirds of the bulbs sold are either 60W, 75W or 100W. The weighted average light bulb wattage is about 75W. Because sales are concentrated in the range of 60-100W, the emphasis in this analysis is on applications now served by 60, 75, and 100W incandescents.

The amount of electricity used for lighting depends directly on the number of hours a light is used. In this analysis, we assume that a typical household has the following simplified usage pattern:

1) Three major lamps (in the kitchen, living room, and main bedroom) are kept on at least four hours per day, 85% of the year, with an average wattage of 75W. With 1240 hours/yr of use, the total electricity consumed by these three lamps is 280 kWh/yr. The 85% annual use factor accounts for vacations and other days with reduced occupancy.

2) Five other lamps are used an average of two hours per day, 85% of the year, the average wattage also being 75W. The total electricity consumed by these lamps is about 230 kWh/yr.

3) One outdoor lamp, 50W on average, is used in 50% of the households for 3100 hours per year. This lamp consumes about 80 kWh/yr per household on the average.

4) Other miscellaneous lights are considered to have much more limited use. These lights consume 410 kWh/yr per household, in order to yield a total consumption of 1000 kWh/yr per household.

It should be noted that lighting usage in the first two categories may be higher than assumed. Since most of the savings potential lies in these categories, this breakdown is conservative with respect to savings. Also, this distribution represents an approximate average for all housing types. Special lighting uses (e.g., common areas of multi-family housing) are not explicitly considered.

B. Energy-efficient technologies

New lighting products introduced in recent years can provide substantial electricity savings. Other advanced lighting technologies are expected on the market in the near-future. They will increase both savings potential and cost-effectiveness.

1. Better incandescents

Incandescent lamps are the least efficient lighting type. The incandescent lamp produces light by using electricity to heat a coiled tungsten filament within a vacuum. Some 90% of the electric energy drawn by the lamp is wasted as heat. Also, tungsten particles burn off, darken the bulb, and reduce the amount of light output by up to 20% over time [7].

Recent developments in the lighting industry have brought to the market slightly improved incandescent bulbs (marketed as "watt-miser" or "supersaver" bulbs). These bulbs are filled with Krypton and have improved filaments. They cost nearly the same as regular incandescents, have the same estimated life, but consume about 6% less electricity per unit of light output. The better bulbs are exactly the same size as common incandescents so there is no installation problem. They are available at wattages 5-10% less than ordinary incandescent bulbs.

The extra list price for the better bulbs is about $0.10 [8].

The actual extra retail price appears to be about the same. Based on a 5W reduction in power consumption over a life of 750 hours, the total electricity savings is 3.75 kWh per bulb. The undiscounted cost of saved energy (CSE) is $0.027/kWh. Since we do not know how a long a bulb will be working, it is difficult to do discounted economic analysis. However, even with a discount rate of 7% and a lifetime of four years, the CSE is still only $0.032/kWh.

2. Coated incandescents

One promising development for incandescent bulbs is a heat reflecting coating for the inside of the bulb, also known as the heat mirror bulb. This bulb is spherical so that the coating reflects infrared radiation back to an improved filament. The optical perfection of bulb and the quality and durability of the coating are of primary importance.

A prototype heat mirror bulb has been developed by the Duro-Test Corporation [9]. It uses about 50% less electricity per unit of light output compared to an ordinary incandescent. It is estimated that a 50W, 1500 lumen version of the heat mirror bulb (which replaces an ordinary 100W bulb) will last 2500 hours and sell for $5.00 [9,10].

To evaluate cost-effectiveness, a heat mirror bulb with these characteristics is compared to a long-life, 100W incandescent. The long-life bulb has the same estimated life (2500 hours) and is assumed to retail for $0.80 [10]. The cost-effectiveness of the heat mirror bulb is considered at usage levels ranging from 50 to 1000 hours per year.

Table 1 shows annual savings and cost of saved energy as a function of use. The CSE value is below $0.07/kWh for usage levels in excess of 100 hrs/yr. The heat mirror bulb would have similar CSE values compared to ordinary incandescents (rather than long-life bulbs). Therefore, if the heat mirror bulb can meet the assumed performance criteria, it is a cost-effective replacement for regular incandescents even at relatively low usage levels.

Table 1 - Electricity Savings and Cost of Saved Energy with the Heat Mirror Coated Light Bulb[a]

Usage (hrs/yr)	Electricity Savings (kWh/yr)	CSE ($/kWh)
50	2.5	0.122
75	3.8	0.088
100	5	0.072
200	10	0.052
500	25	0.041
1000	50	0.038
1240	62	0.037

[a] Based on a 50W heat mirror bulb costing $5.00 and 100W long-life conventional incandescent bulb costing $0.80, each with a light output of 1500 lumens and a rated life of 2500 hours.

There is some concern among lighting experts regarding the durability of the heat mirror bulb [11]. However, Duro-Test claims that the technical problems are solved and that they are starting to mass-produce the bulb in 1985, with test marketing beginning soon after [12]. For this analysis, it is assumed that heat mirror bulbs providing a 50% electricity savings become widely available in 1988.

3. Compact Fluorescents

Fluorescent lamps are up to five times more energy-efficient than incandescents. They convert electricity into light by using an electric charge to excite gaseous atoms inside the tube, which causes the phosphor coating on the inside of tube to emit light. A ballast is required to regulate the current flow. Fluorescent lamps have a relatively long life, with tubes providing up to 20,000 hours of use, compared to 750-1000 hours for incandescents. A fluorescent lamp ballast will last even longer.

Fluorescent lamps have started to make inroads into the incandescent market. All major lighting manufacturers including Philips/Norelco, General Electric, Sylvania, Panasonic and Hitachi have introduced compact fluorescent lamp-ballast combinations in the U.S. These lamps are also widely available in Europe and Japan. The compact fluorescents are screwed into a standard Edison socket. They are available in various wattages from about 10W to 20W for replacing 40W, 60W and 75W incandescents. The compact fluorescents generally have efficacies (light output per unit of power consumed) of 40-60 lumens/Watt, compared to 11-18 lumens/Watt for incandescents.

Compact fluorescents are available as either a complete unit ("SL type"), or as a conversion base containing the ballast with a separate fluorescent tube that plugs into the base ("PL type"). The PL type has the advantage of not requiring replacement of the ballast each time a tube wears out. Also, some models such as the Philips SL18 have a very efficient electronic ballast while others employ an ordinary magnetic core ballast. Unlike most conventional fluorescent lights used in commercial buildings, many of the compact fluorescent bulbs provide "warm" light that is nearly equivalent in color rendition to incandescents [7].

The compact fluorescents now available in the U.S. such as the

Philips SL18 bulb are somewhat longer than ordinary incandescents and will not fit in all fixtures or lamps. Also, the compact fluorescents have not been marketed or promoted for residential use so far. Presumably, this is due to their relatively high first cost, limited production capabilities, lack of familiarity with fluorescents among residential users, and initial emphasis on commercial buildings where usage and cost-effectiveness are greatest.

Compact fluorescent lamp technology is advancing rapidly. Philips/Norelco recently introduced a line of shorter PL tubes and they plan to introduce other new models in the near future [13]. Philips is also developing an electronic ballast that is largely contained on a microchip, cutting size, weight and cost [14]. Mitsubishi recently introduced a line of compact fluorescents in the U.S. and plans additional advanced models in the near future. Osram, a major lighting products manufacturer based in West Germany, produces compact fluorescents in Europe that are very efficient (60 lumens/Watt), provide good quality light, are instant-on, and are about the same size as incandescents [14]. Osram already sells PL tubes in the U.S., and their integral units should become available here before too long.

Considering the technology as a whole, technical advances are expected in the near-term in the areas of ballasts, phosphors and tube production techniques [11].

To evaluate the cost-effectiveness of compact fluorescents, replacements of 60W, 75W, and 100W incandescents are considered. It is assumed that the compact fluorescents have the characteristics shown in Table 2, based for the most part on products currently available in the U.S. The 60 and 100W replacements are assumed to use a core-coil ballast, while the 75W replacement assumes a more-efficient electronic ballast.

Table 2 - Assumed Characteristics of Compact Fluorescent Bulbs

Incandescent replaced	Fluorescent power level	Lifetime (hours)	Light (lumens)	Price ($)
60W	18W	9000	900	15
75W	20W	7500	1200	18
100W	34W	6000	1700	20

The prices for the fluorescents in Table 2 are conservative in that they are based on small purchase quantities. Purchase in bulk should lead to significantly lower costs. For example, Panasonic sells a 17W compact fluorescent individually for about $15, but in bulk to commercial buyers for $10 or lower [14].

The savings and CSE are calculated for each of these replacements assuming high use (1240 hours/yr) and moderate use (620 hours/yr). In addition, the CSE is calculated for the 60W replacement assuming outdoor use (3100 hours/yr). For this comparison, it is assumed that incandescent bulbs cost $0.60 and last 1000 hours [10].

The savings and CSE results are shown in Table 3. It is seen that the CSE ranges from $0.031-0.062/kWh. Thus, today's generation of compact fluorescents are cost-effective relative to PG&E's marginal energy costs.

The diversified peak power savings per bulb shown in Table 3 are relatively low compared to the reduction in installed bulb wattage.

This is due primarily to the afternoon summer peak experienced by PG&E, when domestic lighting is not widely in-use. Cost per unit of conserved peak demand is not shown because the relatively insignificant peak savings leads to very high costs (i.e., the bulbs cannot be justified on the basis of peak power savings).

Table 3 - Savings and Cost-Effectiveness of Compact Fluorescent Bulb Replacements

Replacement option	Use (hrs/yr)	Electricity savings (kWh/yr)	Peak power savings[a] (Watts)	CSE ($/kWh)
60W to 18W	620	26.0	1.66	0.050
60W to 18W	1240	52.0	3.32	0.038
60W to 18W	3100	130.2	--b	0.031
75W to 20W	620	34.1	2.18	0.055
75W to 20W	1240	68.2	4.36	0.044
100W to 34W	620	40.9	2.61	0.062
100W to 34W	1240	81.8	5.23	0.052

[a] Diversified peak power savings assuming CEC's peak-to-average load factor of 0.56.

[b] Replacement of an outdoor light - no lamp use during the peak demand period.

4. Other Advanced Technologies

High-intensity discharge (HID) lamps such as metal halide and high-pressure sodium lamps are even more efficient than fluorescent lamps. But these lamps normally have poor color rendition and are produced at high wattages (50-1000W) [7]. They are used largely for lighting outdoor areas, warehouses, etc.

There have been a number of developments in recent years to improve the color rendition and offer a wider variety of HID lamps. They are beginning to be more widely used in commercial buildings.

Also, there has been some interest in developing HID lamps for residential use.

General Electric has developed a HID bulb known as the "Halarc". A 55W prototype available in 1981-82 produced as much light as a 125W incandescent, and had reasonable color rendition [10]. This bulb also had an estimated life of 5000 hours and a cost of $12. However, the prototype Halarc could only be used "base down". As of 1985, development of the Halarc bulb was suspended.

In this analysis, it is not assumed that HID bulbs become commercially available for residential applications during the 1986-2005 period.

C. Research and Development Recommendations

Research on the way in which consumers use and react to compact fluorescent light bulbs could be of great value. Evidently, some utilities are considering distributing large quantities of these bulbs [14]. If the bulbs are given out or promoted by a utility, it is important to know how they are used and the energy savings that results. Since submetering lights is difficult and costly, having residents subjectively track usage may be sufficient.

Program-oriented research related to efficient lighting technologies is also needed. For example, it remains to be seen whether PG&E is better off selling, giving away, or providing rebates for compact fluorescent bulbs and similar products.

Finally, PG&E could help in testing and test marketing new energy-efficient lighting products such as the heat mirror bulb.

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TECHNOLOGY ASSESSMENT: CENTRAL AIR CONDITIONING

A. Introduction

According to the 1984 Residential Appliances Saturation Survey [1], 59% of the households in the service territory have no air conditioning (or are not sure), nearly 21% have central electric air conditioning (CAC) or heat pumps, 9% have room AC, 8% have evaporative coolers, and 3% other. The end-use model, which applies only to PG&E's electric service area, shows a CAC saturation of 27% in 1985.

The average annual electricity consumption (UEC value) for CAC according to the end-use model is 950 kWh/yr in 1985. This value, based on conditional demand studies, is averaged over all housing units with electric CAC. Of course, space cooling demand depends to a great extent on location; the average UEC for the five climate zones considered in the PG&E forecast ranges from 200 kWh/yr to 1450 kWh/yr in 1985.

In addition to being an important electricity-consuming end-use, residential CAC contributes substantially to summer peak demand. According to the California Energy Commission, residential CAC accounted for 1730 MW or about 12.3% of PG&E's entire peak demand in 1982 [2]. Of all the residential end-uses, space cooling offers the greatest potential for reducing peak demand.

It should be noted that the UEC values assumed in PG&E's end-use forecast are lower than other estimates. Researchers from Lawrence Berkeley Laboratory estimate that a typical 3-ton (36,000 Btu/hr) CAC system in Fresno operates 650 hours/yr and consumes 3600 kWh/yr [3]. The CEC and representatives of the air conditioning industry estimate that the average CAC system in California is used 520-600 hours/yr and consumes 2700 kWh/yr [4]. In PG&E's regions where CAC systems are most common and most intensively used (i.e., the Sacramento, Stockton, and San Joaquin regions), the CEC estimates that average use is closer to 1000 hours/yr [4].

Because of the uncertainties regarding baseline UEC levels and differences in UEC between climate zones and housing types, six prototypical base consumption and demand levels are considered (see Table 1). Operating hours for the baseline systems range from 220-890 hr/yr, corresponding to UEC values of 500-4000 kWh/yr. A seasonal energy efficiency rating (SEER) of 8.0, approximately the average for CAC systems sold during the past five years, is assumed in all cases [10].

Two demand levels are shown for each system in Table 1. The installed demand for any particular CAC system is multiplied by a factor of 0.80 to estimate the diversified peak load (i.e., average peak demand from many households with CAC systems). This adjustment accounts for oversizing of some systems and unoccupied households during the peak period [5]. The estimates of diversified peak demand in Table 1 are consistent with the CEC's estimate of 2.5 kW per unit on the average [4].

Table 1 - Baseline CAC systems

	UEC (kWh)	Cooling Capacity (tons)	Annual Operation (hours)	Installed Demand[a] (kW)	Diversified Peak Demand[b] (kW)
System #1	4000	3.0	890	4.5	3.6
System #2	3000	3.0	670	4.5	3.6
System #3	2000	2.0	670	3.0	2.4
System #4	1500	2.0	500	3.0	2.4
System #5	1000	1.5	440	2.25	1.8
System #6	500	1.5	220	2.25	1.8

[a] Assuming an SEER rating of 8.0

[b] Assuming a diversity factor on peak of 0.8.

B. Technologies for Electricity Conservation

Various approaches for reducing energy consumption and peak power demand due to residential CAC are considered. Most of the options pertain to cooling technologies, although one straightforward shell modification is included. The options are:

1) Window shading;
2) Servicing program for CAC systems;
3) Installing the top-rated CAC systems as of 1985;
4) Indirect evaporative coolers;
5) Thermal storage;
6) Use of home ventilation.

For each option, estimates of savings potential, first cost, and cost-effectiveness are presented assuming replacement of each of the systems shown in Table 1, where appropriate.

1. Window shading

It is estimated that the solar gain through an unshaded west-facing window is typically 200 Btu/hr per square foot (sf) between

4 P.M. and 6 P.M. on a clear day [6]. Likewise, the heat gain through a south-facing window is about 170 Btu/hr/sf between 11 A.M. and 3 P.M. [6]. On the average, it is assumed that west or south windows result in a solar gain of 180 Btu/hr/sf.

A number of techniques are available to reduce solar heat gains through windows, including overhangs, awnings, and window films. By reducing the cooling load, these measures lower cooling system energy consumption.

Window films, the focus of this option, reflect up to 80% of the incident light [7]. Some self-adhesive window films cost less than $2.00/sf of window area. Other more-expensive options include reflective mylar film in a track. The mylar film cuts solar transmission in the summer by about 80%. When not in use, the film is rolled up like a blind. A track system of this type costs about $6.00/sf of window area.

It is estimated that window films with 80% reflectance will reduce cooling load by about 0.1 MBtu/yr/sf of west-facing window area in a climate like Fresno [8]. If we lower this value by 25% to account for partial shading by trees, buildings, etc., the annual savings in electricity consumption is about 10 kWh/sf of window assuming a CAC system of average efficiency. Likewise, peak demand could be reduced about 15 Watts/sf. These estimates are based on a need for about 500 hours of cooling per year.

Table 2 shows the key assumptions and cost-effectiveness results for the two window film options. The two options are evaluated per square foot of window area with savings fixed at the levels presented above. Given the assumptions made, both types of window film appear to be economical on the basis of cost of conserved peak power (i.e., compared to a 20 year marginal peak capacity cost of $670/kW). The self-adhesive film option is also competitive on the basis of energy savings.

Table 2 - Cost-effectiveness of window film options

Option	Cost ($/sf)	Life (yrs)	CSE ($/kWh)	CCPP(20) ($/kW)
Self-adhesive film	2.0	5	0.061	340
Mylar track system	6.0	10	0.107	600

2. Inspection and servicing program for CAC systems

A demonstration project involving the inspection and servicing (I&S) of CAC systems in five homes in Louisiana resulted in average electricity savings of 13.4% [9]. I&S involves checking the refrigerant level, cleaning the coils, inspecting the ductwork for leaks, cleaning the blower, and cleaning or replacing filters.

It is proposed that CAC I&S be done either by PG&E, a contractor, or the resident once a year and that a complete servicing be done every three years for households with relatively high CAC use (UEC > 2000 kWh/yr). At lower usage levels, complete servicing once every five years is proposed. Based on the Louisiana project, it is estimated that the complete servicing costs $50 [9]. Inspection and minor servicing, done in some cases by the resident, should cost about $10 on the average. This leads to average annual costs of $23/yr in the high-use case and $18/yr in the low-use case.

The energy and power savings as a result of regular I&S are estimated to equal 12% with high usage and 10% with low usage. These values are relatively conservative given the Louisiana experience.

Table 3 shows the cost of saved energy and peak power for the prototypical systems defined in Table 1. The I&S program has CSE and CCPP(20) values that are competitive with marginal energy and capacity costs for the two high-use cases. It should be noted that the analysis does not account for any extension of equipment lifetime which is likely to result from an I&S program [9].

Table 3 - Cost-effectiveness of a CAC inspection and servicing program

	CSE ($/kWh)	CCPP20 ($/kW)
System #1	0.048	564
System #2	0.064	564
System #3	0.096	846
System #4	0.120	795
System #5	0.150	1059
System #6	0.300	1059

3. Installing highly efficient CAC systems

As noted earlier, the PG&E residential end-use model subdivides CAC use into five different climate zones. The model selects "option 4" (SEER = 8.0-8.5, plus wall and ceiling insulation) for all CAC installations in the period 1985-1996. For 1997-2005, new installations are split between "option 7" (CAC with SEER = 10.0, shell conforming to new building standards) and "option 10" (heat pump with SEER = 7.65, shell conforming to new building standards).

These CAC and HP efficiencies are not very high - more efficient models are now available and are being adopted to some extent. For example, over 6% of CAC systems manufactured in the U.S. in 1984 (160,000 systems) had SEER ratings greater than 10.0 [10]. The fraction of heat pumps already exceeding a SEER of 10.0 is almost as great.

It is important to recognize that the new minimum efficiency standards for CAC and HP systems adopted by the CEC in 1984-85 exceed the efficiency levels in the PG&E forecast. The standards call for minimum SEER ratings for both CAC and HP systems of 8.9 starting in 1988 and 9.9 starting in 1993 [4,11]. The standards provide a floor on CAC and HP efficiency -- the question examined here is whether or not considerably more efficient models are cost-effective.

Regarding highly efficient CAC systems, major manufacturers including Carrier and Lennox now produce CAC systems with SEER ratings as high as 15.5 [12]. These models include larger heat exchangers, more efficient motors, improved compressors, and in some cases two-speed compressors [13]. The top-rated models are sold in very limited quantities at the present time and carry a substantial first cost premium.

An investigation of actual costs for highly efficient CAC systems conducted in 1984 in Washington, DC found that increasing the SEER of new CAC systems typically costs about $310 per unit of SEER improvement in the range of SEER = 8-13 [14]. The price estimates for three-ton (36,000 Btu/hr) systems are $1500-2000 for a SEER of 8, about $3000 for a SEER of 12.5, and over $4000 for a SEER of 15.5.

Much of the extra first cost in today's market is related to very low production volumes. One industry representative acknowledges that the costs could drop substantially as sales expand and the technology improves [15]. Recent assessments of the actual extra materials, labor and markup costs for increasing CAC system efficiency (such as the analysis carried out by the CEC in its evaluation of CAC standards) shows a first cost premium of only about $200 per unit of SEER in the SEER range of 8-13 [4]. A first cost premium for equipment alone (ie., excluding installation) of $220 per unit of SEER in the SEER range of 8-14 was used in recent study of air conditioner incentive programs conducted for PG&E [16].

Two first cost cases are considered in this evaluation: 1) a first cost premium of $310 per unit of SEER increase based on today's market; and 2) a first cost premium of $155 per unit of SEER increase based on anticipated market expansion and technological developments that bring down costs to consumers. Two shifts in efficiency are considered: 1) shifting from a SEER of 8.5 (close to the average for new systems sold in 1984) to a SEER of 12; and 2) shifting from a SEER of 12 to a SEER of 15. Also, a lifetime of 15 years is assumed for CAC systems [4].

Table 4 shows the cost-effectiveness of the shifts for each of the six prototypical usage levels. It is seen that shifting to a SEER of 12 is only cost-effective at high usage levels (systems 1 and 2) if the low first cost premium is realized. Shifting to a SEER of 15 can be justified based on the CSE in most years at the highest usage level, again with the low first cost premium. In this case, system 2 becomes cost-effective in the late 1990s when the marginal energy supply cost exceeds $0.085/kWh (see Chapter 2). Shifting to either efficiency level cannot be justified for any of the usage levels with the high first cost premium.

Table 4 - Cost-effectiveness of increasing CAC system efficiency

Shifting from an SEER of 8.5 to 12.0

	High cost premium[a] CSE ($/kWh)	High cost premium[a] CCPP(20) ($/kW)	Low cost premium[b] CSE ($/kWh)	Low cost premium[b] CCPP(20) ($/kW)
System #1	0.102	1140	0.052	570
System #2	0.136	1140	0.068	570
System #3	0.204	1710	0.102	850
System #4	0.272	1710	0.136	850
System #5	0.409	2270	0.204	1140
System #6	0.817	2270	0.409	1140

Shifting from an SEER of 12.0 to 15.0

	High cost premium[a] CSE ($/kWh)	High cost premium[a] CCPP(20) ($/kW)	Low cost premium[b] CSE ($/kWh)	Low cost premium[b] CCPP(20) ($/kW)
System #1	0.128	1430	0.064	710
System #2	0.170	1430	0.085	710
System #3	0.256	2130	0.128	1070
System #4	0.341	2130	0.170	1070
System #5	0.511	2850	0.256	1430
System #6	1.022	2850	0.511	1430

[a] Assuming a cost premium of $310 per unit of SEER.

[b] Assuming a cost premium of $155 per unit of SEER.

4. Indirect Evaporative Coolers

Evaporative cooling is a well-established technology. It already accounts for 25-30% of central cooling systems in the PG&E service territory [1]. Direct evaporative coolers, also known as "swamp coolers", utilize the heat of evaporation of water to provide low-cost cooling. A direct evaporative cooler consists of a set of sponge pads, a water pump, and a fan. Direct evaporative coolers have a significantly lower first cost and consume one-tenth to one-fifth as much energy as ordinary CAC systems [17].

The ability of an evaporative cooler to provide comfort is limited primarily by the ambient temperature and humidity. The cooling potential of a direct evaporative cooler in terms of the maximum reduction in air temperature is given by its effectiveness (typically around 80%) times the difference between dry bulb and wet bulb temperatures. In Fresno, for example, this means a maximum cooling potential of about 27°F when the outdoor dry bulb temperature is around 102°F and the wet bulb temperature is 70°F. However, the humidity of the air supplied by the evaporative cooler is around 80% under these design conditions.

There are clearly some drawbacks to commonplace direct evaporative coolers [17]. Most important, they add moisture to indoor air, which some people find undesirable. Also, this can lead to indoor condensation problems. Furthermore, their cooling potential fluctuates with the ambient conditions.

Indirect evaporative coolers overcome the moisture problem. An indirect unit features a regular evaporative cooler plus an air-to-air heat exchanger. While the effectiveness of the indirect stage may be somewhat less than a direct unit (typically 60% rather than 80-90%), it is still much more efficient than a conventional CAC system [18].

Indirect evaporative coolers are being commercially produced by companies in California and Arizona. The company "Vari-Cool" in Santa Rosa, CA is making modular indirect evaporative coolers that are used primarily in commercial buildings so far [19]. However, they can be used in homes and a few systems have been installed for this purpose.

An indirect system can also serve as a pre-cooler connected to either a conventional CAC unit or a direct evaporative cooler. The latter combination is known as a two-stage evaporative cooler. A preliminary investigation found that in Fresno, a "Vari-Cool" two-stage evaporative cooler would have a EER of 30 under design conditions (i.e., full load) [20]. This corresponds to about a 75% electricity savings relative to a conventional CAC system. At partial load, the efficiency and savings would be even greater. A relatively efficient new house in Fresno (with two tons of peak cooling load) would require a two-stage system with about a 2000 CFM (cubic feet per minute of air flow) to provide 78°F indoor air at 60% humidity.

The first cost for installing an indirect evaporative cooler in a new home is around $2000-2500 for a 2000 CFM system [19,20]. Evaporative coolers require regular maintenance especially in areas with hard water, although they do not have expensive breakdowns like regular CAC equipment. Two-stage evaporative coolers can be economically favorable in new homes on the basis of comparable or slightly higher first cost but much lower operating costs compared to a conventional CAC system. They can also be an economical investment when an existing CAC system needs to be replaced.

To demonstrate economic viability, we consider using a two-stage evaporative cooler in a climate like Fresno. It is assumed that: 1) the two-stage evaporative cooler has an effectiveness of 60% and 90% for each stage; 2) it is necessary to supply approximately 1000 CFM of evaporative cooler capacity per ton of cooling demand; 3) the evaporative cooler has an installed cost of $1/CFM (the low end of estimates for residential applications); 4) the indirect evaporative cooler has an EER of 30 under design conditions and an overall SEER of 40; 5) the indirect evaporative cooler replaces a conventional CAC system with a SEER of 8.0 and cost of $600 per ton; and 6) the evaporative cooler and conventional CAC system have similar average maintenance costs and both have a 15 year life.

Table 5 shows the cost-effectiveness results. For all usage levels except system 6, the indirect evaporative cooler appears to be competitive with marginal electricity supply costs on the basis of both energy and peak power savings. If the conventional CAC system was more efficient than what was assumed in this example (SEER = 12 rather than SEER = 8), the first cost of the two-stage evaporative cooler and the conventional CAC system would be comparable. Thus, because of its superior efficiency, the evaporative cooler would again be cost-effective. Although indirect evaporative coolers are mainly used so far in commercial applications, they could become an important technology for reducing power consumption for air conditioning in residences.

Table 5 - Cost-effectiveness of an indirect evaporative cooler[a]

	CSE ($/kWh)	CCPP(20) ($/kW)
System #1	0.025	600
System #2	0.033	600
System #3	0.033	600
System #4	0.044	600
System #5	0.050	600
System #6	0.100	600

[a] Based on indirect evaporative cooler performance in a climate typical of Fresno, assuming the evaporative cooler is used instead of a SEER = 8.0 conventional CAC system.

5. Thermal storage

Thermal storage of "coolth" can be used to shift electricity consumption for domestic cooling from the afternoon peak period to the night off-peak period. Coolth storage is becoming popular in large commercial buildings where it can be used to provide all or part of the space cooling requirement. PG&E already has a program for stimulating the installation of thermal storage in commercial buildings, involving rebates of up to $300 per peak kW saved.

Cool storage systems are not marketed for single family residences at the present time, although it should not be difficult to produce them given recent developments in storage media and the emergence of systems for commercial buildings. Indeed, one system for individual households is close to becoming commercial (see below).

Two thermal storage media, clathrate mixtures and eutectic salts, are most promising. Clathrate is a mixture of water and a noble gas, halogen, or halogenated hydrocarbon. Clathrates have a high latent heat capacity and a variable transition temperature. One system using a water-freon mixture has been developed by TESI, a small company based in San Diego [21]. A prototype unit was retrofit to a residential CAC unit in Southern California at a cost of $140 per ton-hour of storage [21]. Lennox Industries, a major manufacturer of residential space conditioning equipment, recently bought the rights to produce the TESI system. Lennox is studying the feasibility of mass production, which has the potential of reducing costs by about 30%.

A number of companies have overcome the technical problems related to using eutectic salts for thermal storage and systems are available for commercial buildings. The installed storage system cost is $100 per ton-hour or greater, depending on the technique used to encapsulate the eutectic salts and the costs of accessories such as the tank and piping [21].

Two strategies can be employed for cool storage in residential buildings:

1) <u>Partial storage</u>, using a CAC system sized to run continuously under design conditions. On a summer night, the excess cooling output is delivered to the storage system and stored coolth is used to supplement the CAC system the following afternoon. This strategy requires the smallest capacity CAC system and the smallest storage volume.

2) <u>Full storage</u>, also known as demand-limited storage. Here the CAC and storage systems are large enough to shut off the chiller during the peak period. The CAC and storage systems need to be about 40% larger than in the case of partial storage.

Providing full cool storage for an individual household in the PG&E service area requires about 18 ton-hours of storage capacity [21]. This corresponds to an installed cost of $1800-2700 with current clathrate and eutectic salt systems ($100-150 per ton-hour). When used with a three ton cooling system, the cost range for displacing peak demand is $560-840/kW, assuming a storage system lifetime of 15 years. Thus full storage may already be competitive compared to a marginal peak capacity cost of $670/kW, and further experience and mass production should ensure this. Partial storage will be even more cost-effective, especially if it involves downsizing a chiller in new housing.

Other innovations related to residential cool storage should be possible. If a storage medium with a high transition temperature is used, the medium could be partially chilled using cool night air. Simulations done at LBL for the Sacramento and Fresno climates show that, on an annual basis, more than 50% of the cooling could be done naturally, with a corresponding reduction in energy consumption [20]. When supplemental chilling is necessary, it should be possible to charge the storage tank using a direct evaporative cooler, consuming less energy and possibly involving less capital cost compared to the use of a conventional CAC unit.

Another development in cool storage which seems especially promising for small housing units (eg., multi-family housing) is the "ice spot cooler" developed by CALMAC [21]. A 1/6 HP compressor makes ice during off-peak periods generating up to 2 ton-hours of ice. The stored ice is then used for cooling during room occupancy, conceivably during peak load periods. The stored ice provides four hours of cooling at the same rate as a smaller room air conditioner. The estimated price of this portable appliance is $300.

6. Use of home ventilation

When the outdoor ambient temperature is below the indoor temperature and outdoor humidity is not too high, it makes sense to ventilate a building rather than operate a CAC system. This strategy is commonly employed in commercial buildings where it is known as an economizer cycle. One study has shown that ventilation cooling can save a substantial portion of the energy normally used for residential cooling in Northern California [22].

A ventilation cooling system for residential buildings might consist of a whole house fan, a microprocessor control system, temperature and humidity sensors, and remote-controlled vents. Although we are not aware of actual ventilation cooling systems for residential buildings, it should not be difficult to provide such a system using off-the-shelf hardware. We estimate that a ventilation cooling system could be installed for about $1000. In homes that already have a CAC system, it may be possible to retrofit an economizer cycle to the CAC system at a much lower cost.

A preliminary analysis of ventilation cooling was carried out for a single family home in Sacramento using the DOE-2 simulation model [23]. The analysis showed that: 1) there is not likely to be any reduction in peak power demand for air conditioning as ventilation cannot reduce cooling loads on very hot summer afternoons; 2) air conditioning requirements during the morning and night can be reduced substantially; 3) the overall energy savings during the cooling season could reach 50%. The savings depend to some extent on how the

CAC system is operated in the absence of the ventilation system.

Assuming a 50% energy savings can be achieved, Table 6 shows the cost of saved energy for the various prototypical usage conditions. The values in Table 6 are based on a first cost of $1000 and 15 year lifetime. Given these assumptions, the strategy appears to be cost-effective in high-use applications.

A controlled ventilation system could also be used to maintain adequate indoor air quality in very tight new construction.

Table 6 - Cost-effectiveness of ventilation cooling for a single family residence[a]

	CSE ($/kWh)
System #1	0.055
System #2	0.073
System #3	0.110
System #4	0.146

[a] Assuming an installed cost of $1000 and 15 year lifetime.

7. Other technologies

De-superheaters are discussed in detail in the water heating assessment. Besides providing heat recovery for water heating, de-superheaters raise CAC and HP efficiency by providing greater heat exchange capacity. Tests have shown that a 5-10% efficiency gain is possible [24]. Along similar lines, water spray devices are available to cool outdoor coils and raise system efficiency. These options are not considered at greater length because of the limited direct energy savings for cooling.

CAC manufacturers such as Carrier are developing and are optimistic regarding the prospects for continuously variable-speed CAC systems [13]. This technology provides energy savings by matching CAC (or heat pump) output to the load, thereby reducing energy losses due to cycling and heat exchanger loading and unloading. One simulation analysis has shown that a variable-speed heat pump in a single family home in Tennessee uses 27% less energy for space conditioning than a conventional single-speed system [25].

Continuously variable-speed air conditioners and heat pumps are already being produced in large quantities in Japan [26]. Because sophisticated electronics are used to provide variable-speed operation, the Japanese variable-speed units cost 20-30% more than ordinary Japanese AC and HP systems of equivalent size [27]. Unlike AC and HP systems in the U.S., the Japanese systems are through-the-wall split systems (i.e., one fan/coil unit is placed in a wall and the other is placed outdoors). As can be expected, their cost is in between that of room and central systems in the U.S.

Variable-speed CAC systems are not considered as an option in this analysis because of uncertainties regarding performance and cost. Nonetheless, this technology is a likely to be introduced in the U.S. in the near future and it could lead to high-efficiency CAC and HP systems with moderate first cost premiums.

Zonal control is another technology that promises substantial energy savings with CAC or HP systems. Zonal control involves separate thermostat settings in different parts of a household depending on occupancy (e.g., only cooling bedrooms at night during the summer). Automatic controls including a microprocessor are ideal for zonal control. Also, maximum energy savings will occur if zonal control and variable-speed operation are used together [28]. It is estimated that space conditioning energy consumption could be reduced up to 60% if a heat pump includes both of these technologies [28].

Zonal control heat pump and AC systems are produced in Japan, and zonal control heat pumps are starting to be sold in the U.S. by the large air conditioning company Daikin (based here in San Jose, CA) [29]. The Daikin heat pumps feature one outdoor unit containing the motor-compressor as well as a heat exchanger and separate indoor coils placed and controlled in different rooms of the house. Refrigerant lines run between the coils. Thus, an air distribution system is not used. This will significantly reduce installation costs in new housing, besides providing for efficient zonal control.

The energy saving with zonal control CAC or heat pump systems is highly dependent on indoor temperature management. This factor along with cost uncertainties inhibits quantitative analysis. Still, zonal control could provide substantial energy savings over the next 20 years and should be investigated further.

C. Research and Development Recommendations

Many of the strategies discussed above could benefit from further R&D, especially field testing and evaluation. The following specific projects are suggested.

1) Study the costs and savings from a CAC inspection and servicing program. Different levels of expert servicing and customer involvement could be experimented with. Also, the frequency of servicing could be varied.

TECHNOLOGY ASSESSMENT: COOKING RANGES

A. Introduction

According to PG&E's 1983 residential appliance saturation survey [1], electric ranges (consisting of a cooktop and an oven) are found in nearly 58% of the households in the PG&E service territory. According to PG&E's end-use model, a typical electric range consumes 730 kWh/yr, accounting for 7.5% of electricity demand in the residential sector. After refrigerators and lighting, ranges are the most important residential electrical end-use.

Ranges are frequently omitted from analyses of conservation potential. This omission is due to the widespread misperception that no conservation measures can be applied to these devices. In fact, savings of approximately one-half of current electric consumption for cooking is possible using well-identified, tested, and, in some cases, mass-produced technologies.

Electric ranges are also of concern because their saturation is growing, and because of the heavy demand they present during peak load periods (see section C below). Regarding saturation, the end-use model shows electric ranges being used in 75% of single-family homes by the year 2005.

This chapter discusses several technologies that are available for improving the efficiency of electric ranges. It describes what is known about the cost, performance, and technical specifications of these efficiency improvements. Because of the relatively small amount of research that has been performed on this appliance, many of the estimates, particularly of cost, are more tentative than those in the other technology assessments.

The analysis of the conservation technologies applicable to electric ranges and ovens is done based on energy consumption as specified by the Department of Energy (DOE) test procedure. For conventional ranges, there is little difference between the annual energy consumption predicted in this manner and the value assumed by PG&E in its end-use model.

Following the analysis of various efficiency options, the issue of peak demand and demand savings potential is examined. In addition, we discuss the economics of using gas rather than electricity for cooking.

B. Technologies for Electricity Conservation

This section presents two categories of energy conservation measures for electric ranges, with cooktops and ovens considered separately. In the first category, simple measures such as changes in the size or geometry of the burners and the insulation level of the oven are considered. These are technologically straightforward, and reasonably accurate estimates of their cost can be obtained from the research literature. Energy savings from these measures are in the neighborhood of 20 percent. Ranges with these conservation features could become available shortly after a manufacturer decides to implement them; by 1987 if action is commenced promptly.

The second class of measures involves more advanced technologies that alter the methods of heat transfer used in the cooking process. The technologies included are the bi-radiant

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2) Demonstrate and monitor the performance of indirect evaporative coolers. This should be carried out in different climate zones. It would be logical to start in new housing where such systems are most economical. In fact, the Department of Engineering Research at PG&E began an indirect evaporative cooling development and evaluation project in 1985 [30].

3) Further evaluate the additional first cost for highly efficient CAC systems. It would be useful to get some idea what price reductions to expect through market expansion, bulk purchase, and technological improvements. Such information is needed to evaluate incentive, financing and other programs that PG&E could offer.

4) Demonstrate and monitor the performance of cool storage systems. Both full and partial storage should be examined in different climates. Also, cool storage could be tested along with the use of either natural cooling or evaporative cooling.

5) Develop, test and analyze ventilation cooling systems. Integrated systems need to be developed and then field tested. Different operating strategies could be tried during field evaluations, and actual performance compared to that predicted by simulation models.

6) Investigate Japanese variable-speed and zonal control CAC and HP systems. Japanese systems should be acquired and their performance tested. Also, it would be useful to follow the progress in these areas among U.S. manufacturers in order to better evaluate energy savings potential and to develop conservation programs in the future.

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oven and the induction cooktop. Estimates of energy savings for both of these technologies are made. Cost estimates are problematic, although a first attempt at evaluating costs is presented.

The microwave oven is another newer cooking process that could lower electricity consumption for cooking. Tests show that cooking particular food items in a microwave oven consumes 25-75% less energy than using a conventional range [11]. However, it is unclear how much energy will be saved when a microwave oven is available in a household. Consequently, microwave ovens are not included as a technology option.

Table 1 presents a summary of the available conservation measures, their cost, savings, and cost-effectiveness. Due to uncertainties regarding the peak power demand resulting from electric ranges, wide ranges for this parameter are presented in Table 1. Also, the cost of conserved peak power is not calculated due to the uncertainty. This problem is discussed further in section C.

1. Simpler Technologies

Base case electricity consumption is derived from the specifications in a study by Erickson [2]. The efficiency levels in this study are 13.6% for the oven and 69.7% for the cooktop. These result in a base energy consumption of 346 kWh/yr for the oven and 399 kWh/yr for the surface units, for a total of 745 kWh/yr. For comparison, it is estimated in the PG&E end-use model that the average electric range in use in 1985 consumes 742 kWh/yr.

According to Erickson [2], implementation of the simple measures included in the low technology packages in Table 1 produces energy savings of 100 kWh for the oven and 45 kWh for the surface units, roughly 30% and 10% respectively, as summarized in Table 1.

For the oven, the changes involve increasing insulation, which saves 25 kWh, and improving door seals (resulting in less heat loss through infiltration), which saves 34 kWh, reducing the thermal mass of the oven (i.e., the amount of metal used), which saves 27 kWh, and changing the oven element configuration for improved heat transfer, which saves 14 kWh. Erickson claims that all of these measures can be implemented at essentially no cost [2]. In contrast, a Department of Energy analysis concluded that the first cost increase for improvements of this sort would be approximately $26 in 1980 dollars, or $31 in 1985 dollars [3]. However, the DOE analysis did not include the reduction in thermal mass, which lowers the first cost.

The difference between these cost estimates is not significant. The DOE cost estimate would imply a CSE on the order of $0.032/kWh, whereas the Erickson estimate would say that the savings are virtually free. In either case, the CSE is below PG&E's marginal energy costs, and thus pursuit of these savings is cost-effective.

For the surface units, Erickson predicts an energy savings of nearly 34 kWh/yr from reduced contact resistance. He adds the potential for another 11 kWh/yr of savings from improving the reflectance of the reflector pans under the burner, which directs

TABLE 1 - OVERVIEW OF OVEN AND RANGE TECHNOLOGY OPTIONS

	Annual Electricity Use (kWh)	Peak Demand (watts)	Estimated First Cost (1985$)	Extra First Cost (1985$)	Average CSE (1985$/kWh)	Marginal CSE (1985$/kWh)	Estimated Year Available
Baseline							
Oven	346	110-650	$100-$300	0	0	0	1985
Cooktop	399	130-750	$200-400	0	0	0	1985
Simple Technology							
Oven (a)	246	80-450	$100-331	$0-31	$0-.032	$0-.032	1987
Cooktop (b)	355	110-650	$200-404	$0-3	$0-.007	$0-.007	1987
Advanced Technology							
Bi-Radiant Oven	101	30-200	$200-400	$25-100	$.01-.041	$.009-.070	1989
Induction Cooktop	307	100-600	$700-1500	$0-500	$0-.556	$0-1.07	1985

(a) Low technology measures for the oven include increased insulation, improved door seals, reduced thermal mass, and improved heating element configuration.

(b) Low technology measures for the cooktop include better contact resistance and an improved reflector pan.

more heat back toward the cooking utensil. Again, Erickson estimates no increase in first cost due to these cooktop improvements. In comparison, the DOE study suggests a cost increase of $2.70 in 1980 dollars, or about $3.20 in 1985 dollars, but an energy saving of only 9 kWh/yr for reduced contact resistance. This low savings estimate is most likely due to DOE starting from a higher level of efficiency. Even with DOE's cost and savings figures, the CSE is around $0.04/kWh. In Table 1, Erickson's energy savings values are used for consistency.

2. More Advanced Technologies

A major increase in oven efficiency is possible using the "bi-radiant oven" developed by researchers from Purdue University [4]. The bi-radiant oven works by maximizing the use of radiant heat transfer between the oven heating coil and the food. In a conventional oven, the radiation from the heating coil is first absorbed by the walls of the oven, wasting considerable energy in heating up the walls and increasing the conduction heat losses throughout the period the oven is heated. These warm surfaces then heat up the oven air, which finally heats up the food being cooked. In the bi-radiant oven, the walls of the oven are reflective to infrared (heat) radiation, and the baking pan is dark, both of which increase the heat transfer from the coil to the food.

The oven is referred to as bi-radiant because heating coils are provided both above and below the food. Tests of the bi-radiant oven included taste tests of food cooked in the oven [4].

Food quality was found as good as in a conventional oven, and cooking time was reduced as well.

Energy savings with the bi-radiant oven varied with the type of food being cooked, but were typically above 60% [4]. Average energy savings for nine items tested by the researchers was 64.4%. The savings would have been larger had the appropriate pan been used rather than a pan with the wrong reflectivity for two of the nine food tests (which turned in the worst and fourth worst energy performance). For this analysis we assume a 65% energy savings compared to a conventional oven with appropriate conservation measures.

Appropriate conservation measures include those for which savings are not double-counted by combining that measure with the bi-radiant oven. Unfortunately, it is not immediately evident to what extent the savings from the simple measures are overlapping with those of the bi-radiant oven. The bi-radiant oven operates by transferring heat primarily from the heating element to the food. The food then heats up the oven air and the edges of the walls. In contrast, the conventional oven heats up the wall which then heats the air and finally the food. As a result, the wall temperatures are higher in a conventional oven, and loses of heat through conduction are higher. Insulation and thermal mass are likely to have a larger effect in the conventional oven than in the bi-radiant, although their effect in the bi-radiant oven are by no means negligible.

It is assumed that some of the low technology measures (improved door seals and reduced thermal mass) complement the bi-radiant oven, but other measures (improved insulation and better elements) in the package cannot be used in combination with bi-radiant technology. Overall, it is estimated that energy consumption after installation of the bi-radiant feature is 101 kWh/yr, a 71% reduction from the baseline model and a 59% reduction from the low technology package.

The developers of the bi-radiant oven do not estimate the extra cost associated with this technology. But the cost should be relatively low. DOE's cost estimate for increasing insulation, which involves reconfiguring the inside of the oven, a more difficult task than changing the surface finish, is on the order of $25 [3]. Replacing the current oven surface material with a reflective aluminum or other metallic surface may not have any net cost at all; if it does, it is likely to be on the same order of magnitude as the DOE change.

A researcher at Oak Ridge National Laboratory familiar with the bi-radiant oven estimates a first cost increase at the retail level of about $100 [5]. This appears excessive, given the physical changes involved in the bi-radiant oven. (For comparison, the refrigerator/freezer technology assessment shows that major redesigns involving considerably greater change in manufacturing processes and components can be achieved for $75 or less.) Assuming a first cost increase of $100, the incremental CSE for the bi-radiant oven is $0.07/kWh.

Attempts by the Oak Ridge National Laboratory to interest manufacturers in mass-producing the bi-radiant oven have not been successful so far [5]. This is not surprising, given the lack of difference between the efficiencies of ranges currently on the market and the difficulty of selling energy efficiency. Also, ranges are not routinely tested for energy consumption and do not carry Energy Guide labels, so the advantage of the bi-radiant oven would not be obvious to consumers. But, the existence of utility incentives could alter this situation drastically, by allowing the bi-radiant oven to have a lower effective first cost than its competitors, after a rebate is provided.

Once a decision to proceed with production of a bi-radiant oven is made, we estimate a lead time of three years or less for commercialization. This is based on the estimate of a lead time of three years or less for the design changes in refrigerators which appear to be more challenging in general than the changes embodied in the bi-radiant oven. Therefore, we estimate a possible introduction date of 1989 provided that a manufacturer takes the initiative to start the development process promptly.

b. Induction Ranges

Although not widely publicized, induction cooking technology has been used in commercial and residential buildings for about ten years. Induction cooktops are sold and marketed by several different firms, including General Electric Co., Sears, Bacun, Inc., and several Japanese companies.

Induction heating elements for a cooktop feature magnetic coils which are located underneath the cooking area. Running high frequency (20-40 kHz) electricity into a magnetic coil creates an alternating magnetic field which induces a current in a pan. Because of the high resistance, the current is converted to heat. The pans must be made out of or contain iron or steel, however.

Tests of induction cooktops have shown efficiency gains of 20-40% over conventional electrical resistance ranges [6]. This is due to the fact that an induction cooktop heats the cooking utensil directly rather than heating a resistance coil which then transfers the heat to the pan. The stove top itself remains cool. Also, inefficiencies caused by improperly sized or bent cookware or heating elements are eliminated.

The use of improperly-sized utensils appears to be a problem with electric resistance coil cooktops. Often people place pans that should be on a smaller burner on a large one, because they think it will cook faster. This can reduce the efficiency of a conventional burner tremendously, simply because up to 50% of the coil is heating the air and not the pan. This "mismatching" cannot occur with an induction cooktop.

"Temperature control" is vastly different and improved with an induction cooktop. Rather than running continuously, induction units cycle on and off as needed. This controls the heat output and permits "instant heat" as well as continuous heat variability, much like a gas burner. Also, an induction unit shuts off automatically when the pan is removed from the magnetic field.

Current market prices for a range including four induction burners (sometimes including a conventional or convection oven) are between $700 and $1500, depending on whether the unit is counter-top or free-standing. However, the market for induction cooking is quite small at the present time in the U.S. and most units are imported from Japan. Prices are expected to drop through mass production and technological advance to the $300-$400 level by 1992 [6]. Also, ovens using induction heating coils should become commercially available soon.

While energy efficiency is certainly one aspect of the induction cooktop, safety, convenience, and controlability are its primary features. Thus, depending on how one values these features, the extra first cost associated with energy efficiency can vary between $0-$500. Widespread commercialization of induction units would reduce the extra first cost dramatically.

To estimate energy savings and cost-effectiveness, we used a mid-range value of 30% efficiency improvement when compared with the present-day base case. This results in the consumption of 307 kWh/yr, about a 23% reduction from the baseline model and a 14% reduction from the low technology case.

Table 1 shows the CSE values for the wide extra cost range of $0-$500. In order for the incremental CSE to be less than $0.10/kWh, the extra first cost associated with energy efficiency must be limited to about $42. Clearly, other benefits have to be taken into account in order to justify the additional first cost of an induction cooktop.

C. Peak Load Considerations

Ranges make a large contribution to utility peak load, although estimating the magnitude of their contribution to the summer peak is difficult. This section discusses data concerning the contribution of range usage to winter peak loads and discusses the applicability of this data to the summer peak. It concludes that even the winter peak load reductions can have a significant economic effect. Summer peak load reductions, if they actually occur, would be much more valuable than savings in annual energy.

Intuitively, one would expect cooking range use to contribute heavily to peak loads because of standard cooking habits. Most everyone cooks dinner at the same time in the evening, so one would expect to see a sharp peak in power consumption at that time of day. This is confirmed by an empirical study performed by PG&E in association with other utilities [7]; also, PG&E's winter peak load curve shows an additional load of about 1500-2000 MW from 5:00 p.m. to about 7:30 p.m., the time when range use peaks. A peak load to PG&E of 1500 MW corresponds to 680 watts of diversified load per household with an electric range.

The applicability of such information to computing the <u>summer</u> peak is questionable. Intuition also says that on the hottest day of the year, which corresponds to the summer peak day, there is a greatly reduced propensity to cook. People tend to eat salads and other food items that require minimal cooking for the dinner meal, they barbecue rather than cook indoors, or they eat out. The quantitative magnitude of this effect is entirely unknown, however.

One major empirical study of the hourly diversified load characteristics of electric ranges was performed by PG&E in collaboration with the Arizona Public Service Company and Utah Power and Light between October 1972 and December 1973. It is described in an LBL report [7]. This study finds a diversified load of 1400 watts for the hour from five to six p.m., 700 for the preceding hour and 400 watts for the following hour. It also finds a morning peak or 500 watts from 6 to 7 a.m., 400 watts from 7 to 8 a.m., and 300 watts from 8 to 9 a.m.

The California Energy Commission has also examined the issue of peak energy demand due to electric ranges. They estimate a load factor of 2.8 during the period 2:00 p.m. to 6:00 p.m., with a maximum load factor of 3.8 from 4:00 p.m. to 6:00 p.m. [8]. This implies a peak demand of 240-325 watts for an ordinary range. This greatly differs from the values obtained in the PG&E load study. Both the lower and upper bounds are displayed in the peak demand column of Table 1 to provide some estimate of the range of peak savings to be expected. Cost of conserved peak power calculations are not performed because of the large uncertainty in peak load. It is reasonable to conclude, however, that a given percentage reduction in electricity use (through efficiency changes) will result in the same percentage reduction in peak power demand.

D. Electric vs. Gas Ranges

At reasonable levels of cooking energy consumption, approximately 60 therms/year for gas cooking and 750 kWh/yr for electric cooking, gas ranges are considerably lower in annual operating cost. For example, using $0.11/kWh as a typical marginal electricity cost and using PG&E's tailblock rate of $0.81/therm as the marginal cost of gas, the electric range costs $82.50/yr to operate, while the gas range costs only $49.00.

Using gas is more than 40 percent less expensive than using electricity. The differential would be even greater based on gas cooking energy consumption estimated in the PG&E end-use model, 41 therms/yr for households with gas cooking in 1985.

The preferability of gas should not change through the application of advanced technologies. The bi-radiant feature can be applied to gas ovens as well as electric ovens. In fact, savings for a gas-fired bi-radiant oven should be even larger. This occurs because a large percentage of the energy use goes to heating oven air which is exhausted up the flue; consequently, gas ovens are much less efficient than electric ovens. By emphasizing radiant heat transfer rather than convective heat transfer, the efficiency of the gas oven can be improved by a larger percentage than the electric oven. Reducing ventilation losses in gas ovens can be pursued as well.

In addition, large savings for the gas surface unit (burner) have been demonstrated. A new gas technology currently under development is the IR (infrared) jet impingement burner [9]. Using DOE test methods, the efficiency of the IR jet burner is 15-20% greater than that of a conventional gas burner. This implies a 25-30% fuel savings with the IR jet burners. Furthermore, the IR jet burner produces only 13% of the CO emissions, 12% of the NO_x emissions and 8% of the NO_2 emissions of an ordinary gas burner [9].

Field tests of gas ranges equipped with the IR jet burners began in 1984. A commercial unit could be available by late-1986.

By replacing electric ranges with gas, the utility not only saves annual energy costs but also entirely eliminates the peak demand impact of the electric range. If we assume the savings in diversified peak load is typically 500 watts, then the net present value of the savings based on PG&E's marginal peak capacity costs is approximately $300--equivalent to the cost of an inexpensive gas range.

E. Research and Developement Recommendations

As mentioned previously, technical information on energy conservation in electrical cooking technology is sparse. A kitchen technology project now underway at PG&E should help to remedy this situation. Included in this project are cooking experiments with induction cooktops, European-style ceramic cooktops, convection ovens, as well as conventional equipment [10].

It would be useful to test other advanced cooking technologies such as the bi-radiant oven and the IR jet burner as they become available as well. Also, PG&E might attempt a field demonstration and monitoring project with the bi-radiant oven to prove (or disprove) the viability of this technology to itself and to manufacturers.

The issue of peak load from electric ranges is important and appears to be very uncertain. It would be useful to monitor the power consumption of electric ranges according to time of day in a sampling of households. The objective would be to determine the diversified contribution to peak loads from electric ranges.

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Technology Assessment: Clothes Dryers

A. Background

The 1985 PG&E end-use model shows an an overall electric clothes dryer (ECD) saturation of 48% in 1985 and 52.5% by 2005 [1]. ECDs are a major electrical end-use in homes in which they are present. Furthermore, ECDs consume 2-3 times as much electricity as the theoretical minimum amount necessary to remove water from clothes [4].

A variety of options are considered for reducing the electricity consumption of ECDs. One option, a moisture sensor control, can be used in combination with other measures. Other options such as exhaust heat recovery, heat pump, and microwave heating involve more radical changes in design that are mutually exclusive. These latter options are considered both with and without a moisture sensor.

Cost-effectiveness is presented in terms of average CSE, marginal CSE, and marginal CCPP(20). For the options where a moisture sensor is included along with some other feature, marginal CSE and CCPP(20) are calculated relative to a model with only the moisture sensor. For the advanced heat pump ECD, the marginal values are calculated relative to the first generation heat pump.

B. Baseline technology

The ECD technology options in PG&E's end-use model include a baseline that is estimated to consume 932 KWh/yr [1]. The same electricity consumption level is assumed for all housing types.

According to the U.S. Dept. of Energy, the typical ECD sold in 1980 consumed 2.44 KWh/use [2]. This corresponds to 1015 KWh/yr based on 416 uses per year as assumed by DOE. But the appliance industry association (AHAM) claims that 364 uses per year are more typical [3]. This leads to an annual consumption of 888 KWh/yr for the typical 1980 model. Hence PG&E's value of 932 KWh/yr appears to be reasonable as a baseline performance level, and is used in this analysis.

C. Technologies for Electricity Conservation

1. Moisture sensor controls

ECDs are available with sensors that measure either the temperature or the moisture of the exhaust, thereby allowing automatic shut-off of the dryer once the clothes are considered dry. According to U.S. DOE, the majority of the ECDs sold in 1980 included a temperature sensor control [2]. Moisture sensor controls are less common.

Field testing conducted by AHAM as well as testing by the National Bureau of Standards show that use of a moisture sensor and automatic shut-off typically saves 10-15% relative to use of an ordinary manual timer [4]. This feature performs significantly better than use of a temperature sensor for automatic cycle termination [4].

A moisture sensor option is included in PG&E's end-use model with an estimated electricity savings of 124 kWh/yr, a 13.3% reduction relative to the baseline model [1]. This represents a savings of 124 KWh/yr relative to the baseline. These values appear to be reasonable and are used in this analysis.

The end-use model shows an extra first cost of $110 for the moisture sensor option [1]. This is based on prices for actual models in the 1984 Sears catalog [5]. A 1980 study estimated that ECDs with the moisture sensor feature should cost consumers about $50 more [4]. A contractor for U.S. DOE analyzed the extra materials, components, and labor required to produce a model with a moisture sensor and automatic termination, along with slightly more insulation [2]. They estimated that the extra first cost to the consumer should be about $42 (1985$).

It is likely that the Sears price is somewhat inflated compared to actual costs, reflecting novelty value and other factors. For this analysis, it is assumed that the actual cost to consumers for the moisture sensor option is $75, midway between the Sears extra first cost and the estimate made for DOE. As shown in Table 1, this leads to a CSE of $0.060/kWh for the moisture sensor option.

Table 1 also shows that the moisture sensor option (as well as other options) is not economical on the basis of avoided peak demand. This is due primarily to the relatively low peak load factor for ECDs.

2. PG&E advanced option

The ECD technology options in PG&E's end-use model include an "advanced option" with a moisture sensor, additional insulation, and a reduced drying temperature [1,5]. This model is a hypothetical design, and it is estimated to consume 6% less electricity than a unit with just a moisture sensor [5]. However, AHAM has commented that reduced drying temperatures and added insulation are not viable design options [3], in part because lowering the air temperature will increase drying time. This option was removed from the DOE analysis [2]. Consequently, it is not included in this study.

Table 1 - Overview of the Clothes Dryer Technology Options

Option	Moisture sensor	Annual electr. use (kWh)	Peak demand (kW)	Est. first cost (1985$)	Extra first cost (1985$)	Average CSE ($/kWh)	Marginal CSE ($/kWh)	Marginal CCPP(20) ($/kW)	Est. year Avail.
Baseline	N	932	0.166	315	---	---	---	--	1985
Moisture sensor	Y	808	0.144	390	75	0.060	0.060	3410	1985
Exhaust heat recovery	N	792	0.141	415	10	0.071	0.071	4000	1988
	Y	687	0.122	490	17	0.071	0.082	3950	1988
Microwave	N	559	0.099	415	100	0.027	0.027	1490	1992
	Y	485	0.086	490	175	0.039	0.031	5670	1992
First generation heat pump	N	419	0.074	615	300	0.058	0.058	3260	1987/90
	Y	365	0.065	690	375	0.066	0.067	8330	1987/90
Advanced heat pump	Y	243	0.043	750	435	0.063	0.049	2730	1995

3. Exhaust heat recovery

Directly venting the exhaust from an ECD indoors during the space heating season may not be desirable due to the moisture and the lint in the exhaust [4]. However, it is possible to recover heat from the exhaust and use it to heat indoor air via a heat exchanger or preheat incoming air to the clothes dryer.

An experimental dryer with a heat exchanger between incoming and exhaust air has been built and tested by the National Bureau of Standards [7]. It is estimated that an 8°F preheat of incoming air is possible before the exhaust air reaches its condensation (dew) point, thereby resulting in a 5% overall energy savings [4]. Using a rugged heat exchanger that permits condensation in the exhaust would lead to even greater savings. Experiments at one laboratory showed that use of a heat exchanger with condensation of moisture in the exhaust air can lead to 20-26% electricity savings [8].

ECDs with exhaust heat recovery are widely produced and used in West Germany [15]. Many of these are closed cycle systems with moisture condensation and no exhaust venting. However, the German models appear to use room air to condense and cool the dryer air, with little or no direct electricity savings [15].

It is estimated that the heat exchanger and associated equipment would add $100 to the cost of a dryer if mass-produced in the U.S. [8]. Assuming a conservative savings of 15% (about average between the two experimental units described above), the absolute savings would be 140 KWh/yr relative to the baseline model and 121 KWh/yr relative to a unit with a moisture sensor. This leads to a marginal CSE of $0.071-0.082/KWh. The combination of moisture sensor and exhaust heat recovery show an overall CSE of $0.071/KWh relative to the baseline model.

A heat recovery feature could be added to ECDs using off-the-shelf components, and it should be possible to retrofit existing ECDs as well as new units [4]. If manufacturers desired, this feature could be available relatively soon. In this analysis, it is projected that a heat recovery option becomes available in 1988.

4. Microwave clothes dryer

There has been considerable interest in developing a microwave clothes dryer using similar components as in a microwave oven [9]. A prototype has been built and patented by an inventor in Portland. He claims the model has the following characteristics [10]:

- 50% or greater electricity savings;
- 30-50% time savings;
- less tumbling, lint, static and wear.

Also, microwave leakage is supposed to be similar to that with a microwave oven and well within the permissable limit (1 mW/cm^2).

This particular prototype microwave ECD was inspected, tested, and considered for mass production by General Electric in 1985. G.E. found that the unit did perform well (i.e., considerable energy and time savings) with small loads and with larger loads that had limited water retention [9]. However, savings were not obtained with larger loads having high water retention. Although G.E. does not consider the microwave ECD ready for production yet, they believe that the technology shows great promise and will be perfected and commercialized eventually [9].

The inventor of the microwave clothes dryer claims that parts and labor cost about $120 in mass production [10]. He estimates that a microwave ECD should cost only $50-100 more than a conventional ECD at the retail level (about $375-425 in absolute terms). This is consistent with the cost of microwave ovens, which have fallen considerably during the past five years. To be conservative, it is assumed that the microwave ECD costs consumers $100 more than a conventional unit and provides 40% electricity savings on the average. This corresponds to a savings of 373 KWh/yr compared to the baseline model and 323 KWh/yr relative to a model with a moisture sensor and automatic shut-off. It is logical to use automatic controls with the microwave ECD, but exhaust heat recovery may not be feasible due to the inherently lower exhaust temperature.

Based on the assumptions given above, the marginal CSE for the microwave ECD is $0.027-0.031/KWh. Thus the microwave ECD appears to be highly cost-effective. In fact it would still be economical compared to PG&E's marginal energy costs if the extra first cost was twice that assumed.

Regarding the status of the microwave ECD, the engineer dealing with the technology at G.E. estimates that it will be five years before commercialization occurs [9]. For this study, it is assumed that the microwave ECD becomes widely available in 1992.

5. Heat pump clothes dryer

A prototype heat pump ECD has also been developed. This product essentially works like a refrigeration dehumidifier by removing moisture from the dryer air in a closed cycle [11]. Moisture in the air coming from the dryer condenses out on the evaporator coil of the refrigeration system, the dried and cooled air returns to the clothes dryer, and heat is removed from the refrigerant via the condenser coil.

The refrigeration system in the heat pump ECD is similar to that in a room air conditioner. The company that developed the prototype heat pump ECD in the U.S., the Nyle Corporation, already produces commercial-scale dehumidification dryers for drying lumber, food products, and other commodities.

Besides saving energy, the heat pump ECD has about the same drying time as an ordinary dryer, minimal static cling, and potential for operating on 110 Volt power. Also, the dryer has a drain pipe rather than an exhaust vent, making it advantageous for use in multi-family housing where it is difficult to install an exhaust vent.

Tests of the heat pump ECD consistently show energy savings of 50-60% relative to a conventional ECD [11]. The developer claims that the savings could go as high as 70% once the design is perfected [12]. Assuming a conservative energy savings of 55% for a first generation model, the absolute savings would be 513 KWh/yr relative to the baseline model and 444 KWh/yr when a moisture sensor and automatic shut-off are used.

The heat pump ECD uses the same off-the-shelf components (compressor, condenser and evaporator coils, etc.) as a room air conditioner. The developer estimates that when mass-produced, a unit will have a retail price of $600-700, about twice that for an ordinary dryer [12]. This estimate is confirmed by a clothes dryer specialist at Whirlpool who is familiar with the technology [14]. Assuming an extra first cost of $300 for the heat pump feature, the marginal CSE is $0.058/kWh relative to the baseline model and $0.067/kWh relative to a model with a moisture sensor. It is not appropriate to calculate a marginal CSE for the heat pump ECD relative to the exhaust heat recovery or microwave models because these options are mutually exclusive.

The Nyle Corporation intends to produce the domestic clothes dryer on its own at first, and expects to be in production by the end of 1986 [12]. The product will be marketed initially in areas with high electricity prices, a demonstrated committment to energy conservation, and substantial numbers of high-rise apartment buildings. Thus, because of its relatively high electricity prices and support for conservation, the PG&E service territory would be a logical target for early marketing. The Nyle Corporation is also discussing producing the heat pump ECD in a joint venture with a major appliance manufacturer [12].

For this study, two levels of heat pump ECDs are considered. It is assumed that the first generation heat pump ECD with the characteristics described above becomes commercially available and is marketed on a limited scale beginning in 1987, and then becomes widely available in 1990. A second generation heat pump ECD is projected to become available in 1995.

The second generation heat pump ECD is assumed to have a more efficient compressor and other improvements that result in an energy savings of 70% relative to the baseline model. When a moisture sensor is included, the overall savings would be about 74%. If these efficiency improvements add $60 to the price of the first generation heat pump ECD, the marginal CSE relative to the first generation heat pump would be \$0.049/KWh and the overall CSE relative to the baseline model would be \$0.063/KWh.

It should be noted that heat pump clothes dryers are already produced and sold in Japan. Hitachi markets a unit that is placed in the ceiling of the bathroom. Clothes are hung in the bathroom to dry, and the drying time is typically 2-4 hours [13]. It is estimated that this unit provides a 30-40% energy savings relative to a conventional dryer [13]. Hitachi is also developing a self-contained heat pump ECD.

D. Electric vs. Gas Clothes Dryers

A conventional electric ECD consuming 930 kWh/yr costs \$102/yr to operate assuming residential customers pay a tailblock rate of \$0.11/kWh. A typical gas clothes dryer with electric ignition consumes about 40 therms/yr and costs only \$32/yr to operate assuming a tailblock rate of \$0.81/therm. Thus, gas clothes dryers are much more economical to use. Even advanced ECDs consuming 400-500 kWh/yr would be more costly to operate than gas dryers at today's energy prices.

According to the Sears Catalog [16], gas dryers cost \$40 more than equivalent electric dryers. But the need for professional installation could increase the difference in first cost to \$100 or more. Still, gas dryers are likely to be more economical for consumers on the basis of life-cycle cost. It is sensible for PG&E to promote them as a means for reducing electricity demand.

E. Research and Development Recommendations

It would be useful for PG&E to encourage the development and commercialization of the advanced clothes dryer technologies. One way this could occur is through support for product R&D (as PG&E is now doing with refrigerators). The microwave ECD is a good candidate for such a project because of its apparent savings potential and cost effectiveness.

PG&E could also conduct field testing of prototypes or initial production models when they become available. Both the heat pump and microwave ECDs are logical candidates for field testing.

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PART III - SCENARIOS ANALYSIS

Chapter 9 - Methodology

A. General Methodology

Three different electricity consumption scenarios are developed. The scenarios estimate total electricity consumption and peak power demand for the seven end-uses under consideration through the year 2005. The objective of the scenarios analysis is to determine the maximum conservation potential in the PG&E service area based on the efficiency options considered to be technically and economically feasible.

The first scenario is a base case, close to PG&E's 1985 end-use forecast. There are moderate improvements in the efficiency of new equipment, but significant growth in total consumption still occurs. The second scenario is a current technology (CT) case, which assumes a high penetration of energy-efficient technologies now widely available over the next 20 years. This results in relatively flat electricity consumption for the seven end-uses through 2005. The third scenario is a technical potential (TP) case, which assumes a high penetration of both currently available and advanced technologies over the next 20 years. This leads to a substantial reduction in total electricity consumption by the year 2005.

The scenarios analysis is based to a large extent on the PG&E end-use model. For each end-use considered, the size of the appliance stock over time is derived from the end-use model. New purchases and retirements are estimated by first assuming that the retirements in any year are equal to 0.7 times the stock that year divided by the assumed product life. The factor of 0.7 accounts for the growth in the appliance stock over time (ie., older models are being retired, and the stock of older models is less than the stock of newer models due to growth in housing and saturation). The number of new purchases in any year are then calculated based on the stock and retirement values.

The same values for new purchases, retirements, and equipment stocks are used in all three scenarios. This is consistent with excluding any fuel switching or early retirement from the analysis. Therefore, energy savings is limited to some extent in the analysis by the normal turnover in appliances. It would be straightforward to modify the analysis to incorporate either fuel switching or early retirement if so desired.

In order to estimate overall energy consumption and peak power demand over time, assumptions are made regarding the energy consumption of new and retired models year-by-year, as well as the total energy consumption of the equipment stock in 1985. The latter value is derived from the end-use model.

For most of the products of interest, the end-use model is also used as the source for data on the average unit energy consumption (UEC) of new and retired appliances in the base case. The end-use model includes various technology options and performs a life-cycle cost analysis to establish the efficiency and energy consumption of new products over time. In general, the end-use model shows modest improvements in the efficiency of new products in the future, although in some cases efficiencies do not increase until the mid-1990's or later. It is noted that the technology options now incorporated in PG&E's end-use model were provided by a contractor in 1984 [1], but are based to a large extent on an original assessment published by the U.S. Dept. of Energy in 1980 [2]. The latter study is now somewhat outdated.

Lighting is not listed as a separate end-use in the PG&E model; instead it is included as part of miscellaneous energy consumption. As discussed in the technology assessment, electricity consumption for lighting is estimated to equal 1000 kWh per household per year in the base case. Efficiency improvements are made in the CT and TP cases in a similar manner as for the other end-uses. Lighting is analyzed solely on the basis of household electricity consumption per year because of the difficulty in tracking new purchases and retirements.

In the case of water heaters and manual defrost freezers, the assumptions in the end-use model for new appliance UEC are not followed because they are judged to be inconsistent with current practice and expectations for the future. In these cases, we believe that the UEC values for new purchases in the end-use model are too low.

The CT and TP scenarios are developed by making new assumptions regarding the UEC of new and retired appliances over time. In the CT case, more energy-efficient options now widely available and determined to be economical in the technology assessments are phased in through new purchases. As described below, the more-efficient options are assumed to achieve high penetrations among new purchases relatively quickly. The average UEC of retired appliances during the 1985-2005 time period is adjusted to be consistent with the assumptions for new appliances.

In the TP case, advanced technologies deemed cost-effective are also phased into the equipment stock through new purchases beginning when these technologies are assumed to become commercially available. In some cases, new purchases are divided among a number of more efficient options in any one year. The complete set of assumptions regarding new product type and UEC are described below by end-use.

The CT and TP scenarios also assume that the new appliance standards adopted by the California Energy Commission go into effect and are adhered to. These standards apply to refrigerators, freezers, air conditioners, and heat pumps. In the base case, with efficiency assumptions derived from PG&E's 1985 end-use model, the new appliance standards are not factored in. (It is expected that the end-use model will be modified in the future to incorporate the new standards.)

The scenarios track peak demand as well as overall electricity consumption. Aggregate summer peak demand is estimated for the different end-uses and scenarios using the same peak-to-average load factors described in the methodology section of Part II (Chapter 2).

Practically speaking, the scenarios are developed through creating one or more worksheets for each end-use in each scenario. The worksheets are provided in the appendices. For ranges, clothes dryers, and lighting, there is one worksheet per scenario. Central air conditioning is analyzed separately in five different climate zones (in the same manner as in PG&E's end-use model). Consequently, there are five CAC worksheets per scenario. Manual defrost and automatic defrost refrigerators and freezers are analyzed separately. Also, electric water heating is analyzed separately for single family housing and other housing types because of differences in occupancy and UEC by housing type.

B. New purchase UEC assumptions in the scenarios

The assumptions regarding technology options, penetrations, and new purchase UEC values are described by end-use in this chapter. All three scenarios are covered. Continuous reference is made to the options in the technology assessments since they serve as the basis for the UEC assumptions in the different scenarios.

1. Refrigerators and freezers

Frost-free refrigerators

For automatic defrost refrigerators, it is assumed in the base case scenario that the average UEC of new models falls from 1127 kWh/yr in 1985 to 950 kWh/yr by 1992, and remains constant thereafter. These values are averages for all frost-free refrigerator styles.

In the CT scenario, the following assumptions are made:

1) During 1987-88, the average new model consumes 900 kWh/yr, about a 14% drop from the base case. This conforms with the new CEC standards that go into effect in 1987.

2) During 1989-91, the average new model consumes 750 kWh/yr. This is the performance level for the most efficient model now widely produced in the U.S.

3) During 1992-2005, the average new model consumes 600-650 kWh/yr. This is consistent with the efficiency standards adopted by the CEC that go into effect in 1992.

The following assumptions are made for new purchases in the TP scenario:

1) During 1987-88, the average new model consumes 900 kWh/yr.

2) During 1989-91, 50% of new purchases are at the level of 750 kWh/yr

and 50% are at 600 kWh/yr.

3) During 1992-95, 50% of new purchases are at 600 kWh/yr and 50% are at 460 kWh/yr, the performance level indicated by the "low technologies" package of measures described in the technology assessment.

4) During 1996-2000, 50% of new purchases are at 460 kWh/yr and 50% are at 385 kWh/yr, the latter representing the "intermediate technologies" measures. The intermediate technologies should become available by the early 1990s and are expected to be cost-effective on the basis of marginal CSE during the late 1990s.

5) During 2001-2005, 50% of new purchases are at 385 kWh/yr and 50% are at 176 kWh/yr, the latter representing the "advanced technologies" model. As described in the technology assessment, the advanced model appears to be very cost-effective with a marginal CSE less than the intermediate measures. The average new product UEC during 2001-2005, 280 kWh/yr, is 70% lower than that in the base case scenario.

Manual defrost refrigerators

In the base case scenario, it is assumed that the new product UEC is 695 kWh/yr for 1985-87, 580 kWh/yr for 1988-1991, and 436 kWh/yr for 1992-2005.

The following assumptions are made for manual defrost refrigerators in the CT scenario:

1) During 1987-88, the average new model consumes 500 kWh/yr. This conforms with the 1987 minimum efficiency standard.

2) During 1989-91, the average new model consumes 450 kWh/yr.

3) During 1992-2005, the average new model consumes 400-425 kWh/yr. This is in the vicinity of the most efficient models now produced and also satisfies the 1992 standard.

In the TP scenario, the assumptions are as follows:

1) During 1987-88, the average new model consumes 500 kWh/yr.

2) During 1989-95, 50% of new purchases average 425 kWh/yr and 50% average 270 kWh/yr. The latter value represents the low technologies package evaluated in the technology assessment.

3) During 1996-2005, 50% of new purchases consume 270 kWh/yr and 50% average 110 kWh/yr, the performance level for the package of advanced efficiency measures.

Frost-free freezers

The assumptions for freezers are similar to those for refrigerators. In the base case scenario derived from the end-use model, the new model UEC remains constant at 1137 kWh/yr during the entire time period.

In the CT scenario, it is assumed that the new CEC standards are complied with, leading to an average UEC of 1050 kWh/yr during 1987-88, 950 kWh/yr during 1989-91, 820 kWh/yr during 1992-95, and 750 kWh/yr during 1996-2005. The UEC level during the 1996-2005 period is still slightly above that of the low technology option considered in the technology assessment.

In the TP scenario, it is assumed that:

1) During 1987-88, the minimum standard is satisfied with new models consuming 1050 kWh/yr on the average.

2) During 1989-91, 50% of purchases consume 1050 kWh/yr and 50% are at 680 kWh/yr. The latter represents the low technology options included in the assessment.

3) During 1992-95, 50% of purchases consume 680 kWh/yr and 50% consume 420 kWh/yr, the intermediate technologies performance level.

4) During 1996-2005, 50% of purchases consume 420 kWh/yr and 50% consume 235 kWh/yr. The latter corresponds to the advanced technologies package of measures.

Manual defrost freezers

PG&E's end-use model shows all new purchases in the 1985-2004 time period consuming 484 kWh/yr. This is considerably less than the average new model today (about 780 kWh) and is even less than the best model now available. Therefore, the base case scenario is adjusted so that new purchases begin at today's typical consumption level and reach 484 kWh/yr by 1992. Consumption of 484 kWh/yr is close to the 1992 CEC requirement, assuming the separate standards for chest and upright freezers are averaged together.

In the CT scenario, the following assumptions are made:

1) During 1987-88, new purchases average 650 kWh/yr.

2) During 1989-91, new purchases average 550 kWh/yr.

3) During 1992-2005, new purchases average 400-450 kWh/yr. This conforms with the CEC's new efficiency standards.

In the TP scenario, the assumptions are as follows:

1) During 1987-88, new purchases average 650 kWh/yr.

2) During 1989-91, 50% of purchases consume 550 kWh/yr and 50% consume 300 kWh/yr, the latter being the performance of the low technology package of measures.

3) During 1992-95, 50% of new purchases consume 300 kWh/yr and 50% consume 245 kWh/yr, as indicated by the intermediate measures in the technology assessment.

4) During 1996-2005, 50% of new purchases consume 245 kWh/yr and 50% consume 135 kWh/yr. The latter represents the advanced technologies

model evaluated in the technology assessment.

A comment on the relative shares of the different refrigerator and freezer types is warranted. The new purchase and equipment stock assumptions are derived from PG&E's end-use model. However, it is felt that new purchases of manual defrost refrigerators are overestimated in the model in comparison to purchases of automatic defrost refrigerators, and that automatic defrost freezer purchases are excessive in relation to purchases of manual defrost freezers. These judgements are based on data regarding product class shares from AHAM, the industry association representing refrigerator and freezer manufacturers [3]. The relative fractions have not been adjusted in the scenarios.

2. Electric water heaters

In PG&E's end-use model, all new purchases beginning in 1982 are assumed to be heat pump water heaters. This is not representative of the marketplace in recent years, and is not likely to be realistic in the near future unless dramatic changes occur. Therefore, a separate base case scenario is developed.

In all scenarios, new purchase UEC levels are determined based on assumptions concerning average hot water demand and the average energy factor (i.e., efficiency) of new units. Measures to reduce both energy factor and hot water demand are evaluated in the technology assessment. Single family housing and other housing types (multi-family housing and mobile homes) are analyzed separately, as discussed in the technology assessment.

Table 1 displays the UEC levels for new water heaters purchased between 1985 and 2005. In all scenarios, it is assumed that hot water demand drops from 50 gal/day to 40 gal/day during the 20 year period in single family housing. In multi-family housing, hot water use drops from 31 gal/day to 26 gal/day.

Regarding technology options, it is assumed that average HPWHs are widely adopted in new single family homes in the base case (in accordance with the new building code). In the CT scenario, the best HPWH as of 1985 is widely adopted. In the TP scenario, advanced HPWHs begin to purchased during the 1990s. In multi-family housing and mobile homes, it is assumed that efficiency improvements are not as great as in single family housing, due to reduced hot water use, higher costs per unit of savings, and institutional barriers.

Table 1 - New water heater UEC values

	UEC level by scenario (kWh/yr)					
	Single family housing			Other housing		
Year	Base	CT	TP	Base	CT	TP
1985	4030	4030	4030	2500	2500	2500
1986	4030	3290	3160	2500	2420	2270
1987	3870	1790	1610	2500	2420	2270
1988	3870	1790	1610	2500	2420	2270
1989	3590	1790	1610	2120	2020	1810
1990	3590	1790	1610	2120	2020	1810
1991	3450	1640	1350	2120	2020	1810
1992	3450	1640	1350	2120	2020	1810
1993	3450	1640	1350	2120	2020	1810
1994	3450	1640	1350	2120	2020	1810
1995	3450	1490	1350	2120	1540	1290
1996	2980	1490	1350	1810	1540	1290
1997	2980	1490	1350	1810	1540	1290
1998	2980	1490	1100	1810	1540	1290
1999	2030	1490	1100	1810	1540	1290
2000	2030	1490	1100	1810	1540	1290
2001	2030	1490	1100	1810	1540	1290
2002	2030	1490	1100	1810	1540	1290
2003	2030	1490	1100	1810	1540	1290
2004	2030	1490	1100	1810	1540	1290
2005	2030	1490	1100	1810	1540	1290

3. Lighting

In the base case scenario, annual electricity consumption for lighting is kept constant at 1000 kWh per household during 1985-2005. For the CT and TP scenarios, overall energy consumption for lighting is evaluated using the same categories of lights as in the technology assessment.

The following assumptions are made for the CT scenario:

1) For infrequently used lights, better incandescents with a 6% savings penetrate 25% of the market in the 1987-88 period, 50% of the market in the 1988-91 period, and 100% of the market beginning in 1992.

2) For the three major lights (assumed to be used 1240 hrs/yr), compact fluorescents providing 70% savings where installed penetrate 10% of the market in the 1987-88 period, 25% of the market in the 1989-91 period, 50% of the market in the 1992-95 period, and 100% of the market in the 1996-2005 period.

3) For the five other commonly used lights (620 hrs/yr each), compact fluorescents providing savings of 70% penetrate 10% of the market in the 1987-88 period, 20% of the market in the 1989-91 period, 40% of the market during 1992-95, and 70% of the market in 1996 and thereafter.

4) For outdoor lighting, compact fluorescents providing 70% savings penetrate 25% of the market by 1987-88, 50% of the market by 1989-91, and 100% of the market beginning in 1992.

These assumptions take into account the greater cost-effectiveness of compact fluorescent retrofits where usage is highest. They also are meant to be conservative regarding savings potential taking into account near-term practical problems such as bulb size when trying to replace incandescents with fluorescents.

The assumptions result in the values shown in Table 2 for lighting electricity use in an average household over time. It is seen that total kWh use per household drops nearly 40% between 1985 and 1996.

For the TP case, no change is made in the penetration assumptions for the major lights, five other lights, or outdoor lighting. In the case of other miscellaneous lights, it is assumed that the heat mirror bulb begins penetrating the market in 1989, and replaces 50% of ordinary incandescents by 1996. The remaining portion of the miscellaneous lights are again assumed to be slightly improved incandescents.

Table 3 shows overall potential electricity use per household over time in the TP case. Here electricity use per household falls nearly 50% between 1985 and 1996.

Table 2 - Overall Electricity Consumption for Lighting, Current Technology Scenario

	KWH USE PER HOUSEHOLD				
Time period	3 major lights	5 other lights	Misc. lights	Outdoor lighting	TOTAL
1985-86	280	230	410	80	1000
1987-88	260	214	404	66	944
1989-91	210	198	398	52	858
1992-95	182	166	385	24	757
1996-2005	84	117	385	24	610

Table 3 - Overall Electricity Consumption for Lighting, Technical Potential Scenario

Time period	KWH USE PER HOUSEHOLD 3 major lights	5 other lights	Misc. lights	Outdoor lighting	TOTAL
1985-86	280	230	410	80	1000
1987-88	260	214	404	66	944
1989-91	210	198	377	52	837
1992-95	182	166	340	24	712
1996-2005	84	117	295	24	520

4. Central air conditioners

The PG&E end-use model evaluates central air conditioning separately in five different climate zones. The average UEC value for new models in 1985 ranges from 180-1400 kWh/yr depending on the climate zone. Most of the installations, however, are in zones 2 and 3, the most cooling intensive zones with the highest UEC levels.

The new product efficiency and UEC assumptions in the base case scenario are identical to the PG&E model, even though the values in the model appear to be somewhat low. In zone 2, the new model UEC drops from 950 kWh/yr in 1985 to 750 kWh/yr in 1996 and then 650 kWh/yr in 2003. In zone 3, the new model UEC drops from 1400 kWh/yr in 1985 to 1200 kWh/yr in 1996 and then 1100 kWh/yr in 2004. It should be noted that the UEC and overall energy consumption values for central air conditioners also include heat pumps used for cooling.

For the CT and TP scenarios, UEC reduction factors are generated. The reduction factors, shown in Table 4, are multiplied by the new product UEC values in the base case. The factors result from the savings and penetration assumptions described below, which in turn are based on the CAC technology assessment. Many of the measures are complementary, so the overall savings potential is substantial. Also, separate assumptions are made for cooling intensive areas (zones 2 and 3) and non-intensive areas (zones 1, 4, and 5).

Table 5 - UEC multipliers for new CAC installations

Current technology scenario

Time period	Cooling zones 2 and 3	Cooling zones 1, 4 and 5
1986-87	0.739	0.767
1988-91	0.640	0.688
1992-96	0.539	0.624
1997-05	0.485	0.608

Technical potential scenario

Time period	Cooling zones 2 and 3	Cooling zones 1, 4 and 5
1986-87	0.710	0.767
1988-91	0.404	0.624
1992-96	0.208	0.559
1997-05	0.157	0.486

The assumptions used to generate the reduction factors apply to new CAC purchases, both for new housing and for replacement systems. Unless noted otherwise, the percent savings in annual electricity consumption and peak demand are assumed to be equal.

The assumptions for the CT scenario are as follows:

1) Window film is used along with 50% of new CAC installations in 1986-87 and 100% of installations in 1988 and thereafter. This provides a 10% reduction in cooling load, and is included in all cooling zones. An inspection and servicing program is not included due to its

questionable cost-effectiveness.

2) The efficiency of new conventional CAC systems is increased relative to the base case due primarily to the new CEC efficiency standards. The average SEER of new purchases is assumed to equal 9.7 during 1987-91, 10.7 during 1992-96, and 12.0 during 1997-2005. This results in 15-25% less electricity consumption for new installations relative to the base case.

3) Conventional CAC systems are replaced by indirect evaporative coolers in some installations in the hottest areas (climate zones 2 and 3). For the CT scenario, it is assumed that indirect evaporative coolers replace 10% of new conventional CAC systems during 1986-91, 25% during 1992-96, and 40% during 1997-2005 in these zones. Furthermore, it is assumed that indirect evaporative coolers provide an 80% energy and peak demand savings relative to the base case.

For the TP scenario, the same assumptions are made regarding window film as in the CT scenario. Other assumptions are as follows:

1) The efficiency of conventional CAC systems is increased to SEER = 12 during 1992-2005. This provides a 25-31% savings relative to the base case.

2) Evaporative coolers again replace some conventional CAC systems in the hottest climate zones. The fraction of new installations assumed to be evaporative coolers in the TP scenario is 10% during 1986-87, 25% during 1988-91, 50% during 1992-96, and 75% during 1997-2005.

3) It is assumed that thermal storage becomes available and is adopted along with 10% of new installations during 1988-91, 25% during 1992-1996, and 50% during 1997-2005. Furthermore, it is assumed that thermal storage where used totally eliminates peak demand, but

provides no energy savings.

5. Cooking ranges

The assumptions regarding the average UEC of new electric ranges in the base case scenario are derived from PG&E's end-use model. The average UEC of new purchases remains constant at 760 kWh/yr during 1985-2002. Modest efficiency improvements occur during 2003-2005.

For the CT scenario, the UEC assumptions are identical to those in the base case. This is due to the apparent lack of energy savings features now commercially available and the lack of efficiency standards for ranges.

For the TP scenario, it is assumed that 50% of new purchases during 1987-88 are at the base performance level and 50% are at the level indicated by the "low technologies" package described in the technology assessment. During 1989-91, it is assumed that 25% of purchases are at the base UEC, 50% include the low technologies features, and 25% are advanced models (featuring an induction cooktop and bi-radiant oven). During 1992-2005, it is assumed that 50% of purchases include the low technology measures, and that 50% are advanced models. This results in an average UEC of 508 kWh/yr for new purchases during 1992-2005, 33% less than the predominant UEC in the base scenario.

6. Clothes dryers

The average UEC of new electric clothes dryers in the base case scenario are similar to that in PG&E's model. During 1985-1994, the average UEC is 808 kWh/yr, which corresponds to a clothes dryer that includes a moisture sensor. The average new product UEC then gradually declines to 700 kWh/yr by 2005 in the base case.

For the CT scenario, the assumptions are identical to those in the base case. Once again, this is due to the lack of commercially available savings options at the present time in the U.S.

For the TP scenario, the same new product UEC as in the base and CT cases is maintained through 1987. During 1988-91, it is assumed that 50% of new purchases have the moisture sensor feature and that 50% use the first generation heat pump. During 1992-95, it is assumed that new purchases are split evenly between the first generation heat pump and microwave clothes dryers. Finally, during 1996-2005, it is assumed that 50% of new purchases are an advanced heat pump and 50% are a microwave model. Also, it is assumed that all new models include a moisture sensor control after 1992.

C. Notes and References

1. "Pacific Gas and Electric Residential Sector Technology Options Documentation", Energy and Resource Consultants, Inc., Boulder, CO, July 20, 1984.

2. "Energy Efficiency Standards for Consumer Products", DOE/CS-0166, U.S. Department of Energy, 1980.

3. "1983 Energy Consumption and Efficiency Data for Refrigerators, Refrigerator-freezers, and Freezers", Association of Home Appliance Manufacturers, Chicago, July 1, 1984.

RESULTS OF THE SCENARIOS ANALYSIS

A. Results by scenario

The detailed calculations of energy consumption and peak power demand by end-use for 1985-2005 are contained in 42 worksheets presented in Appendices A, B, and C. (One appendix is devoted to each scenario). Tables 1-6 in this chapter summarize the results for each scenario. The first three tables pertain to electricity consumption while the latter three tables pertain to peak power demand. The end-use abbreviations used in the tables are: REF - refrigerators, FRE - freezers, EWH - electric water heaters, LTG - lighting, CAC - central air conditioners, RAN - ranges, and CLD - clothes dryers.

Table 1 shows that in the base case scenario, overall electricity consumption for the seven end-uses increases 37.4% between 1985 and 2005. At the same time, the end-use model shows a 49.5% increase in the number of households during the same period (equivalent to a 2.0% annual growth rate). Thus, electricity consumption per household for the seven major end-uses declines about 8% over the 20 year period in the base case scenario.

Total electricity consumption in the base case is about 2% greater than in PG&E's end-use model in 1985, about 4% greater during the 1990's, and 3.5% greater in 2005. This is due to differences in efficiency assumptions for water heating and manual defrost freezers between the two projections.

Table 2 shows that in the current technology scenario, total electricity consumption for the seven end-uses remains relatively constant during the 1985-2005 period. The estimate for the year

Table 1

Summary Electricity Consumption
Base Case Scenario

Electricity consumption (GWh/yr)

Year	REF	FRE	EWH	LTG	CAC	RAN	CLD	TOTAL
1985	4701	1270	1614	3597	878	1595	1503	15,158
1986	4750	1277	1691	3677	904	1651	1535	15,486
1987	4790	1282	1757	3756	931	1711	1564	15,791
1988	4817	1284	1824	3830	960	1765	1590	16,071
1989	4835	1282	1872	3896	990	1814	1614	16,303
1990	4854	1277	1916	3966	1021	1863	1636	16,532
1991	4877	1271	1962	4038	1052	1914	1663	16,777
1992	4891	1267	2008	4122	1085	1972	1693	17,039
1993	4906	1263	2054	4204	1121	2026	1720	17,294
1994	4921	1257	2096	4290	1159	2086	1753	17,561
1995	4942	1255	2137	4380	1199	2146	1781	17,840
1996	4965	1253	2173	4475	1230	2208	1814	18,119
1997	4993	1252	2218	4572	1263	2274	1846	18,417
1998	5018	1250	2253	4670	1296	2341	1877	18,704
1999	5046	1248	2289	4768	1331	2406	1911	19,000
2000	5079	1247	2313	4868	1370	2476	1940	19,293
2001	5108	1245	2354	4969	1410	2545	1970	19,602
2002	5143	1245	2388	5070	1452	2618	2002	19,918
2003	5177	1244	2431	5172	1493	2680	2035	20,233
2004	5218	1245	2469	5274	1530	2734	2065	20,533
2005	5255	1245	2508	5376	1567	2778	2093	20,823

Table 2

Summary Electricity Consumption
Current Technology Scenario

Electricity consumption (GWh/yr)

Year	REF	FRE	EWH	LTG	CAC	RAN	CLD	TOTAL
1985	4701	1270	1614	3597	878	1595	1503	15,158
1986	4741	1277	1656	3677	886	1651	1535	15,424
1987	4739	1278	1642	3546	893	1711	1564	15,372
1988	4740	1278	1628	3616	894	1765	1590	15,512
1989	4705	1271	1607	3343	895	1814	1614	15,248
1990	4670	1262	1579	3403	895	1863	1636	15,308
1991	4637	1253	1549	3465	895	1914	1663	15,376
1992	4595	1241	1520	3120	885	1972	1693	15,027
1993	4552	1229	1489	3182	878	2026	1720	15,077
1994	4508	1216	1462	3248	871	2086	1753	15,143
1995	4469	1205	1435	3316	866	2146	1781	15,217
1996	4418	1190	1421	2730	857	2208	1814	14,638
1997	4368	1175	1426	2789	847	2274	1846	14,724
1998	4317	1159	1440	2849	839	2341	1877	14,822
1999	4266	1144	1463	2908	835	2406	1911	14,934
2000	4217	1129	1479	2969	832	2476	1940	15,042
2001	4165	1113	1500	3031	832	2545	1970	15,157
2002	4116	1098	1521	3093	833	2618	2002	15,282
2003	4065	1083	1555	3155	841	2680	2035	15,414
2004	4018	1069	1585	3217	847	2734	2065	15,534
2005	3967	1054	1616	3279	854	2778	2093	15,643

Table 3

Summary Electricity Consumption
Technical Potential Scenario

Electricity consumption (GWh/yr)

Year	REF	FRE	EWH	LTG	CAC	RAN	CLD	TOTAL
1985	4701	1270	1614	3597	878	1595	1503	15,158
1986	4704	1277	1650	3677	884	1651	1535	15,378
1987	4702	1278	1627	3546	889	1698	1564	15,304
1988	4703	1278	1606	3616	873	1740	1557	15,373
1989	4649	1264	1577	3261	856	1762	1548	14,917
1990	4594	1248	1539	3320	838	1785	1538	14,862
1991	4542	1234	1496	3380	819	1807	1530	14,808
1992	4472	1208	1453	2935	783	1819	1511	14,179
1993	4401	1181	1408	2993	748	1827	1489	14,047
1994	4329	1153	1367	3054	711	1838	1469	13,922
1995	4260	1127	1331	3119	677	1849	1446	13,808
1996	4156	1091	1308	2327	642	1860	1418	12,802
1997	4053	1054	1303	2377	605	1873	1389	12,656
1998	3947	1017	1296	2428	571	1885	1361	12,506
1999	3841	980	1302	2479	539	1896	1333	12,370
2000	3735	943	1302	2531	510	1908	1303	12,232
2001	3595	904	1305	2584	484	1920	1275	12,067
2002	3457	866	1310	2636	456	1935	1249	11,910
2003	3320	828	1328	2689	446	1949	1225	11,787
2004	3189	789	1344	2742	436	1967	1201	11,670
2005	3061	750	1361	2796	426	1989	1178	11,561

2005, 15,643 GWh/yr, is only about 3% higher than estimated consumption in 1985. Correcting for growth in population and housing, electricity consumption per household for the seven end-uses declines 31% between 1985 and 2005 in the CT scenario.

Table 3 shows the electricity consumption results for the technical potential scenario. Here absolute consumption for the seven end-uses declines about 24% between 1985 and 2005. Taking into account population and housing growth, consumption per household drops 49% over the 21 year period in the TP scenario.

It is worth noting once again that the seven end-uses considered account for about 70% of total residential electricity consumption in 1985. Accepting the the value for overall growth in electricity consumption for other miscellaneous end-uses between 1985 and 2005 in PG&E's end-use model (1.1%/yr on the average), total electricity consumption for the entire residential sector would still fall nearly 10% in absolute value between 1985 and 2005 in the TP scenario.

Tables 4, 5, and 6 show the estimates of peak power demand in each of the scenarios. Between 1985 and 2005, summer peak demand is estimated to increase nearly 57% in the base case scenario and 8% in the CT scenario. Peak demand grows faster than overall electricity consumption because air conditioning increases in importance relative to the other end-uses.

In the TP scenario, it is estimated that peak demand declines 32% between 1985 and 2005 for the seven end-uses. The percentage reduction in peak demand over the 20 year period is greater than the percentage reduction in electricity consumption because of the very large savings that are assumed for central air conditioning.

Table 4

Summary Peak Power Demand
Base Case Scenario

Peak Power Demand (MW/yr)

Year	REF	FRE	EWH	LTG	CAC	RAN	CLD	TOTAL
1985	626	167	200	230	1665	512	267	3,667
1986	633	168	209	235	1714	530	273	3,762
1987	638	169	217	241	1764	549	278	3,856
1988	642	169	226	245	1820	566	282	3,950
1989	644	169	231	250	1876	582	287	4,039
1990	647	168	237	254	1934	598	291	4,128
1991	650	167	243	259	1994	614	295	4,221
1992	652	167	248	264	2056	633	301	4,320
1993	654	166	254	269	2124	650	305	4,423
1994	656	166	259	275	2197	669	311	4,532
1995	658	165	264	281	2272	688	316	4,645
1996	661	165	269	287	2331	708	322	4,744
1997	665	165	274	293	2392	730	328	4,847
1998	669	165	278	299	2455	751	333	4,950
1999	672	164	283	305	2523	772	339	5,059
2000	677	164	286	312	2596	794	345	5,173
2001	681	164	291	318	2672	816	350	5,292
2002	685	164	295	325	2751	840	356	5,415
2003	690	164	301	331	2829	860	361	5,535
2004	695	164	305	338	2899	877	367	5,644
2005	700	164	310	344	2970	891	372	5,752

Table 5

Summary Peak Power Demand
Current Technology Scenario

Peak Power Demand (MW/yr)

Year	REF	FRE	EWH	LTG	CAC	RAN	CLD	TOTAL
1985	626	167	200	230	1665	512	267	3,667
1986	632	168	205	235	1679	530	273	3,721
1987	631	168	203	227	1693	549	278	3,749
1988	631	168	201	232	1694	566	282	3,776
1989	627	167	199	214	1695	582	287	3,771
1990	622	166	195	218	1696	598	291	3,786
1991	618	165	192	222	1696	614	295	3,802
1992	612	164	188	200	1678	633	301	3,774
1993	606	162	184	204	1664	650	305	3,776
1994	601	160	181	208	1650	669	311	3,780
1995	595	159	177	212	1641	688	316	3,789
1996	589	157	176	175	1624	708	322	3,750
1997	582	155	176	179	1604	730	328	3,753
1998	575	153	178	182	1590	751	333	3,763
1999	568	151	181	186	1582	772	339	3,780
2000	562	149	183	190	1576	794	345	3,799
2001	555	147	185	194	1577	816	350	3,824
2002	548	145	188	198	1579	840	356	3,854
2003	542	143	192	202	1593	860	361	3,893
2004	535	141	196	206	1606	877	367	3,928
2005	529	139	200	210	1619	891	372	3,959

Table 6

Summary Peak Power Demand
Technical Potential Scenario

Peak Power Demand (MW/yr)

Year	REF	FRE	EWH	LTG	CAC	RAN	CLD	TOTAL
1985	626	167	200	230	1665	512	267	3,667
1986	627	168	204	235	1675	530	273	3,712
1987	626	168	201	227	1686	545	278	3,731
1988	627	168	199	232	1655	558	277	3,715
1989	619	166	195	209	1622	565	275	3,652
1990	612	164	190	213	1588	572	273	3,613
1991	605	163	185	216	1552	580	272	3,573
1992	596	159	180	188	1483	583	268	3,457
1993	586	156	174	192	1417	586	264	3,375
1994	577	152	169	196	1348	590	261	3,292
1995	568	148	165	200	1283	593	257	3,213
1996	554	144	162	149	1216	597	252	3,073
1997	540	139	161	152	1147	601	247	2,987
1998	526	134	160	156	1082	605	242	2,904
1999	512	129	161	159	1021	608	237	2,827
2000	498	124	161	162	966	612	231	2,755
2001	479	119	161	165	916	616	227	2,683
2002	460	114	162	169	865	621	222	2,613
2003	442	109	164	172	845	625	218	2,576
2004	425	104	166	176	826	631	213	2,541
2005	408	99	168	179	808	638	209	2,509

B. Comparison of scenarios

Tables 7 and 8 display total electricity consumption and peak demand over time in the three scenarios as well as the savings relative to the base case. The savings are also displayed graphically in Figures 1 and 2. Table 9 summarizes the percentage changes within and between the different scenarios.

In relation to the base case, electricity consumption in the CT scenario drops 14.7% by 1995 and 24.9% by the year 2005. The absolute savings in 2005 is 5180 GWh/yr. This is equivalent to the power delivered from about 1070 MW of baseload capacity, assuming a 60% capacity factor and 8% T&D losses.

In comparing the TP scenario to the base case, overall electricity consumption declines 22.6% by 1995 and 44.5% by 2005. The absolute savings in 2005, 9260 GWh/yr, is equivalent to the power delivered from about 1900 MW of baseload capacity, again assuming a 60% capacity factor and 8% T&D losses.

Table 8 and Figure 2 show the enormous potential reduction in peak summer demand. By the year 2005, the estimated peak demand savings reaches 1790 MW in the CT scenario and 3240 MW in the TP scenario. The former value represents a 31% reduction from the base case while the latter value represents a 56% reduction.

Figures 3 and 4 display electricity consumption for the various end-uses and scenarios in the years 1995 and 2005. These graphs show the relative importance of the different end-uses as well as the areas offering the greatest savings potential. The savings values in 2005 are also presented in Table 10.

Table 7

Overall Comparison of Scenarios
Total Electricity Consumption

	Electricity Consumption (GWh/yr)			Savings relative to Base Case (GWh/yr)	
Year	Base Case	CT Case	TP Case	CT	TP
1985	15,158	15,158	15,158	0	0
1986	15,486	15,424	15,378	63	108
1987	15,791	15,372	15,304	419	487
1988	16,071	15,512	15,373	559	697
1989	16,303	15,248	14,917	1054	1385
1990	16,532	15,308	14,862	1224	1670
1991	16,777	15,376	14,808	1401	1969
1992	17,039	15,027	14,179	2012	2859
1993	17,294	15,077	14,047	2217	3247
1994	17,561	15,143	13,922	2419	3640
1995	17,840	15,217	13,808	2623	4032
1996	18,119	14,638	12,802	3482	5317
1997	18,417	14,724	12,656	3693	5761
1998	18,704	14,822	12,506	3882	6198
1999	19,000	14,934	12,370	4066	6630
2000	19,293	15,042	12,232	4250	7060
2001	19,602	15,157	12,067	4445	7535
2002	19,918	15,282	11,910	4637	8008
2003	20,233	15,414	11,787	4819	8446
2004	20,533	15,534	11,670	4999	8863
2005	20,823	15,643	11,561	5181	9262

Notes: CT - current technology; TP - technical potential.
Applies only to the 7 residential end-uses considered.

Table 8

Overall Comparison of Scenarios Peak Power Demand

	Peak Demand (MW/yr)			Savings relative to Base Case (MW/yr)	
Year	Base Case	CT Case	TP Case	CT	TP
1985	3,667	3,667	3,667	0	0
1986	3,762	3,721	3,712	41	50
1987	3,856	3,749	3,731	107	125
1988	3,950	3,776	3,715	174	235
1989	4,039	3,771	3,652	268	386
1990	4,128	3,786	3,613	342	515
1991	4,221	3,802	3,573	420	648
1992	4,320	3,774	3,457	546	863
1993	4,423	3,776	3,375	647	1048
1994	4,532	3,780	3,292	753	1240
1995	4,645	3,789	3,213	856	1432
1996	4,744	3,750	3,073	993	1671
1997	4,847	3,753	2,987	1094	1860
1998	4,950	3,763	2,904	1187	2046
1999	5,059	3,780	2,827	1279	2232
2000	5,173	3,799	2,755	1374	2418
2001	5,292	3,824	2,683	1468	2609
2002	5,415	3,854	2,613	1562	2803
2003	5,535	3,893	2,576	1643	2959
2004	5,644	3,928	2,541	1717	3103
2005	5,752	3,959	2,509	1792	3243

Notes: CT - current technology; TP - technical potential.
Applies only to the 7 residential end-uses considered.

Figure 1

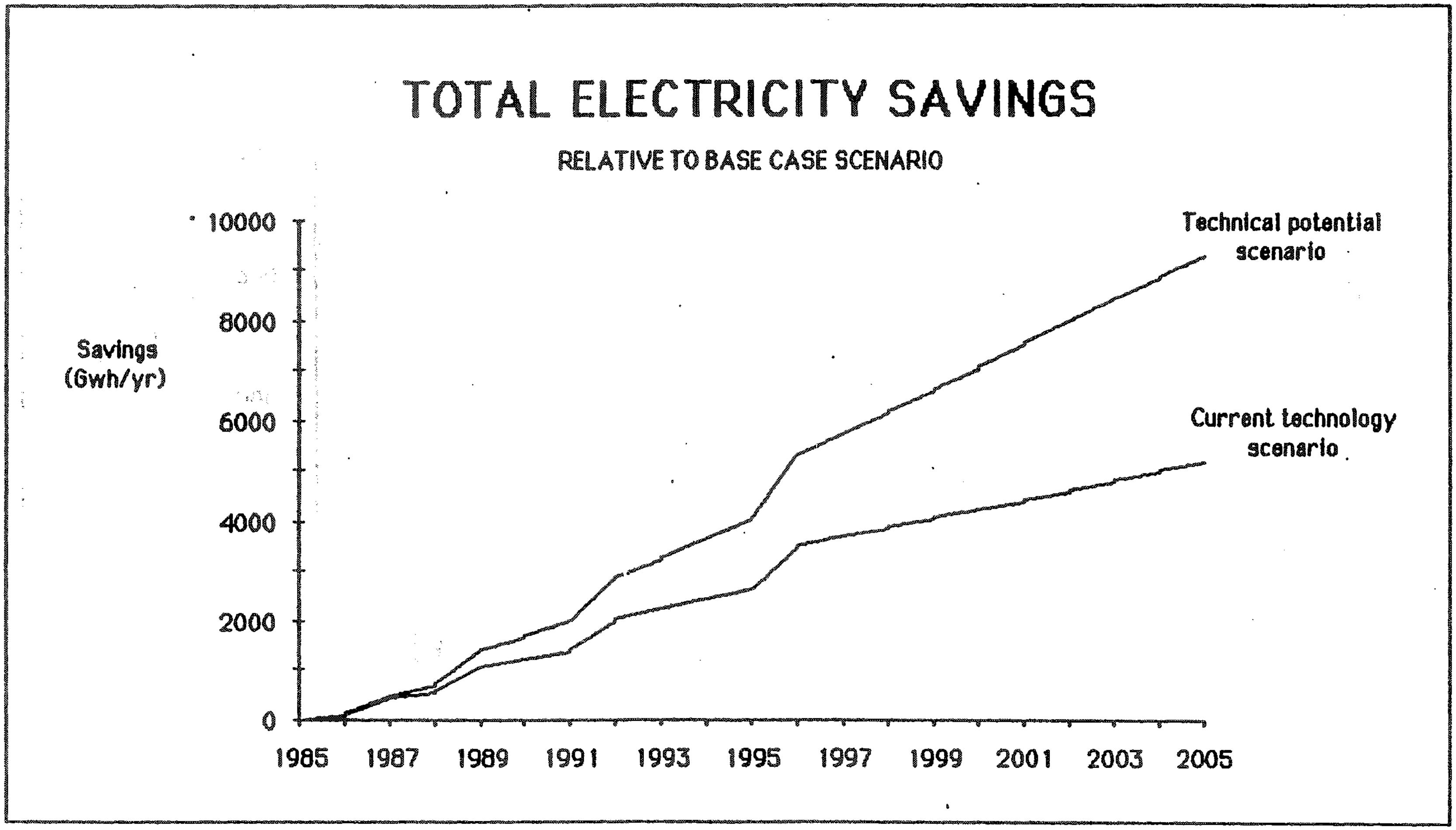

TOTAL ELECTRICITY SAVINGS
RELATIVE TO BASE CASE SCENARIO
Savings (Gwh/yr)
10000
8000
6000
4000
2000
0
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Technical potential scenario
Current technology scenario

Figure 2

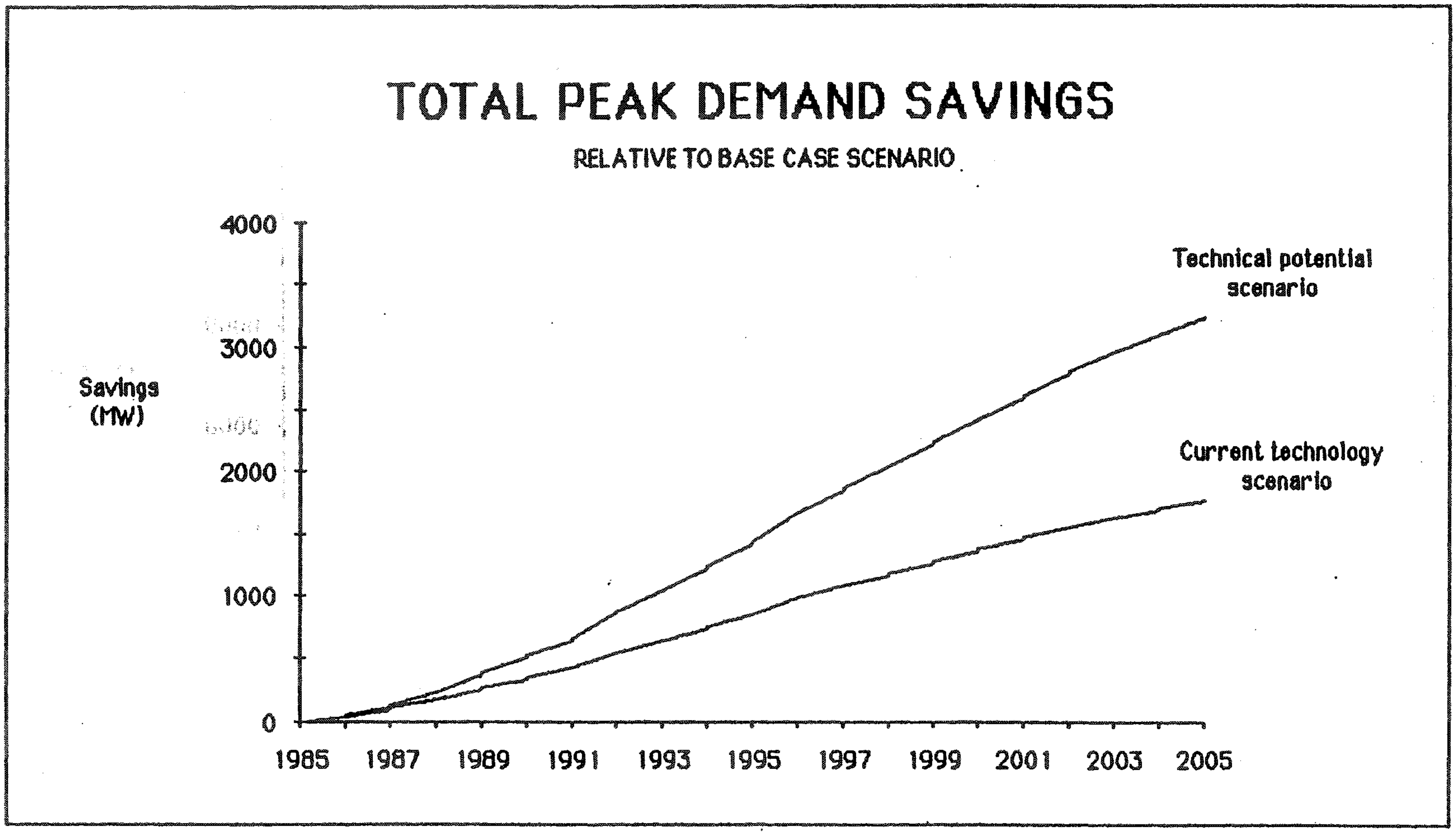

TOTAL PEAK DEMAND SAVINGS
RELATIVE TO BASE CASE SCENARIO
Savings (MW)
4000
3000
2000
1000
0
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Technical potential scenario
Current technology scenario

Table 9 - Changes in energy consumption and peak power demand in the scenarios

	Base Scenario	Current Technology Scenario	Technical Potential Scenario
Change in electricity consumption (1985-2005)	+37%	+3%	-24%
Change in el. consumption per household (1985-2005)	-8%	-31%	-50%
Change in peak power demand (1985-2005)	+57%	+8%	-32%
Change in peak demand per household (1985-2005)	+5%	-28%	-55%
Change in el. consumption in 2005 relative to base scenario	--	-25%	-44%
Change in peak demand in 2005 relative to base scenario	--	-31%	-56%

Refrigerators and lighting are clearly the end-uses that can provide the most electricity savings. In the CT scenario, lighting represents about 40% of the electricity savings and refrigerators account for about 25% of the total electricity savings identified in the year 2005. Water heaters and central air conditioners account for about 17% and 14% of the total savings respectively in that year.

In the TP scenario, lighting accounts for 28% of the electricity savings and refrigerators account for 24% of the savings in 2005 relative to the base case. Water heaters, central air conditioners, ranges and clothes dryers each account for 8.5-12.5% of the total savings in 2005 in this scenario.

Figures 5 and 6 display the summer peak demand estimates in 1995

Figure 3

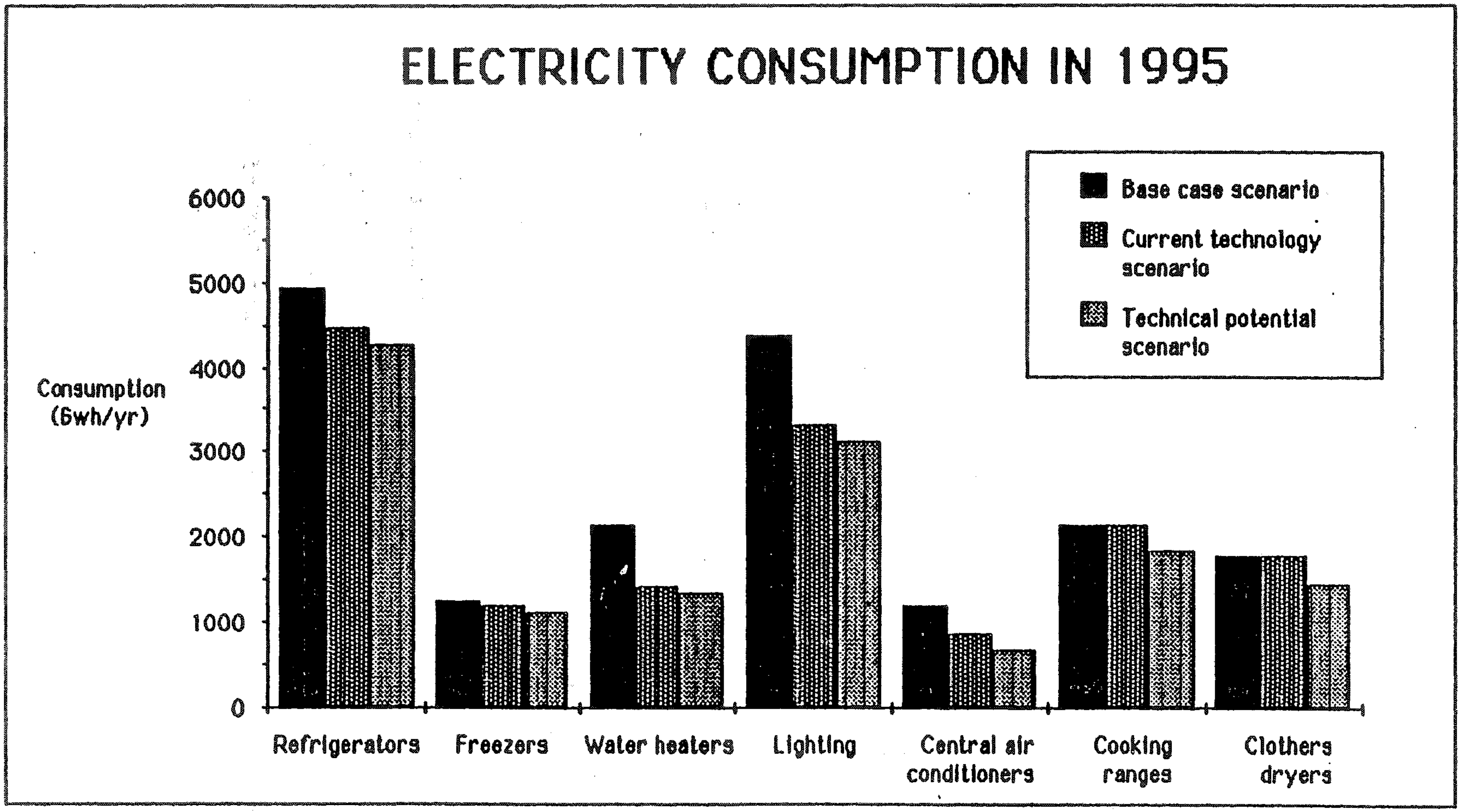
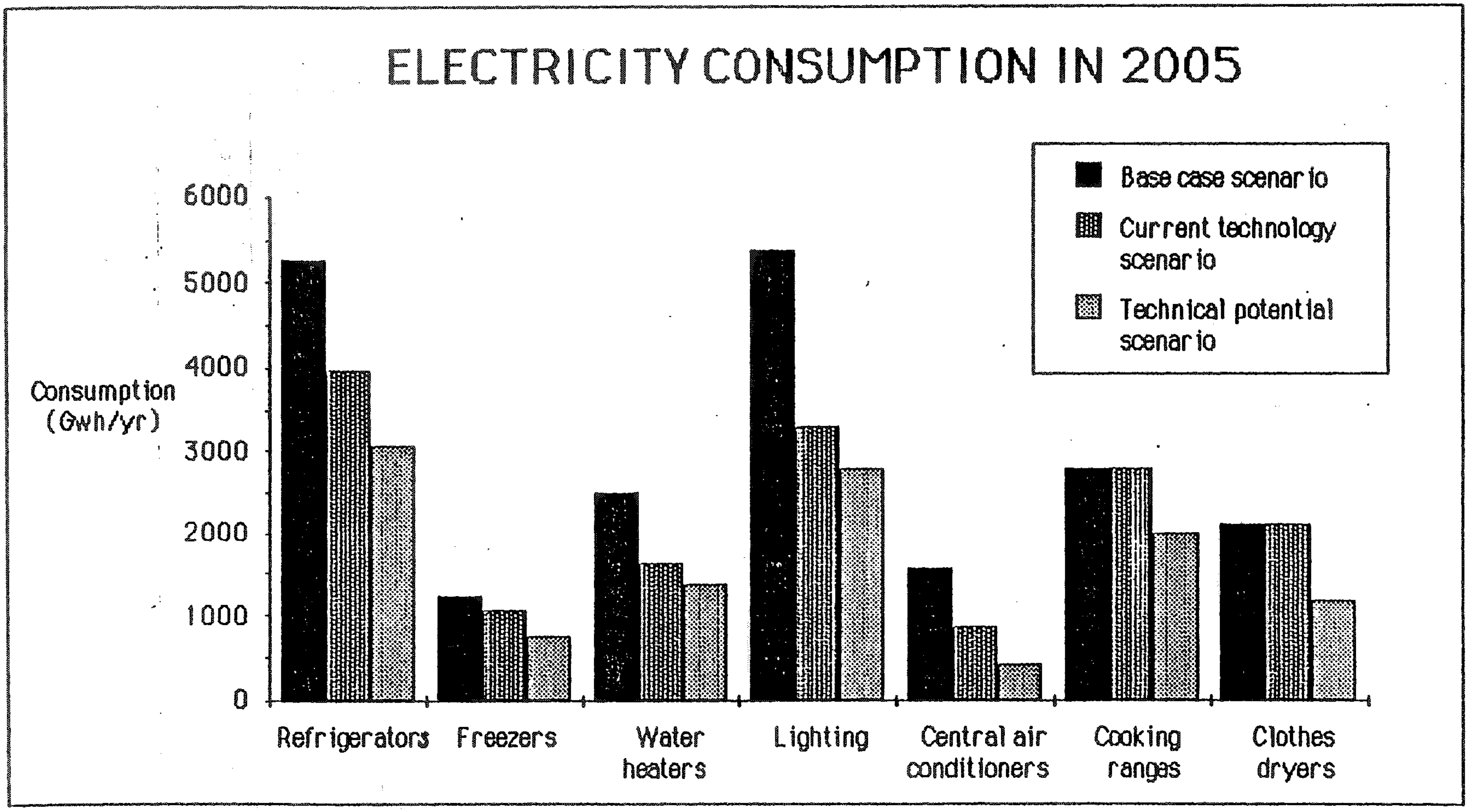

ELECTRICITY CONSUMPTION IN 1995
Base case scenario
Current technology scenario
Technical potential scenario
Consumption (Gwh/yr)
6000
5000
4000
3000
2000
1000
0
Refrigerators
Freezers
Water heaters
Lighting
Central air conditioners
Cooking ranges
Clothers dryers

Figure 4



ELECTRICITY CONSUMPTION IN 2005
Base case scenario
Current technology scenario
Technical potential scenario
Consumption (Gwh/yr)
6000
5000
4000
3000
2000
1000
0
Refrigerators
Freezers
Water heaters
Lighting
Central air conditioners
Cooking ranges
Clothes dryers

and 2005 according to end-use and scenario. Again, the data for 2005 are presented in Table 10. Here the importance of air conditioning stands out. Two-thirds of the potential reduction in summer peak demand by the year 2005 is associated with central air conditioning in the TP scenario. This fraction is even higher in the CT scenario. After air conditioning, refrigerators and ranges appear to offer the greatest peak demand savings potential.

Table 10 - Savings potential in 2005 relative to the base scenario

A. Electricity use (GWh)

End-use	Current Technology Scenario	Technical Potential Scenario
Refrigerators	1288 (25%)	2194 (24%)
Freezers	191 (4%)	495 (5%)
Electric water heating	892 (17%)	1147 (12%)
Lighting	2097 (40%)	2580 (28%)
Central air conditioning	713 (14%)	1141 (12%)
Ranges	0 --	789 (9%)
Clothes dryers	0 --	915 (10%)
TOTAL	5180 (100%)	9260 (100%)

B. Summer peak demand (MW)

End-use	Current Technology Scenario	Technical Potential Scenario
Refrigerators	171 (10%)	292 (9%)
Freezers	25 (1%)	65 (2%)
Electric water heating	110 (6%)	142 (4%)
Lighting	134 (8%)	165 (5%)
Central air conditioning	1351 (75%)	2162 (67%)
Ranges	0 --	253 (8%)
Clothes dryers	0 --	163 (5%)
TOTAL	1790 (100%)	3240 (100%)

Figure 5

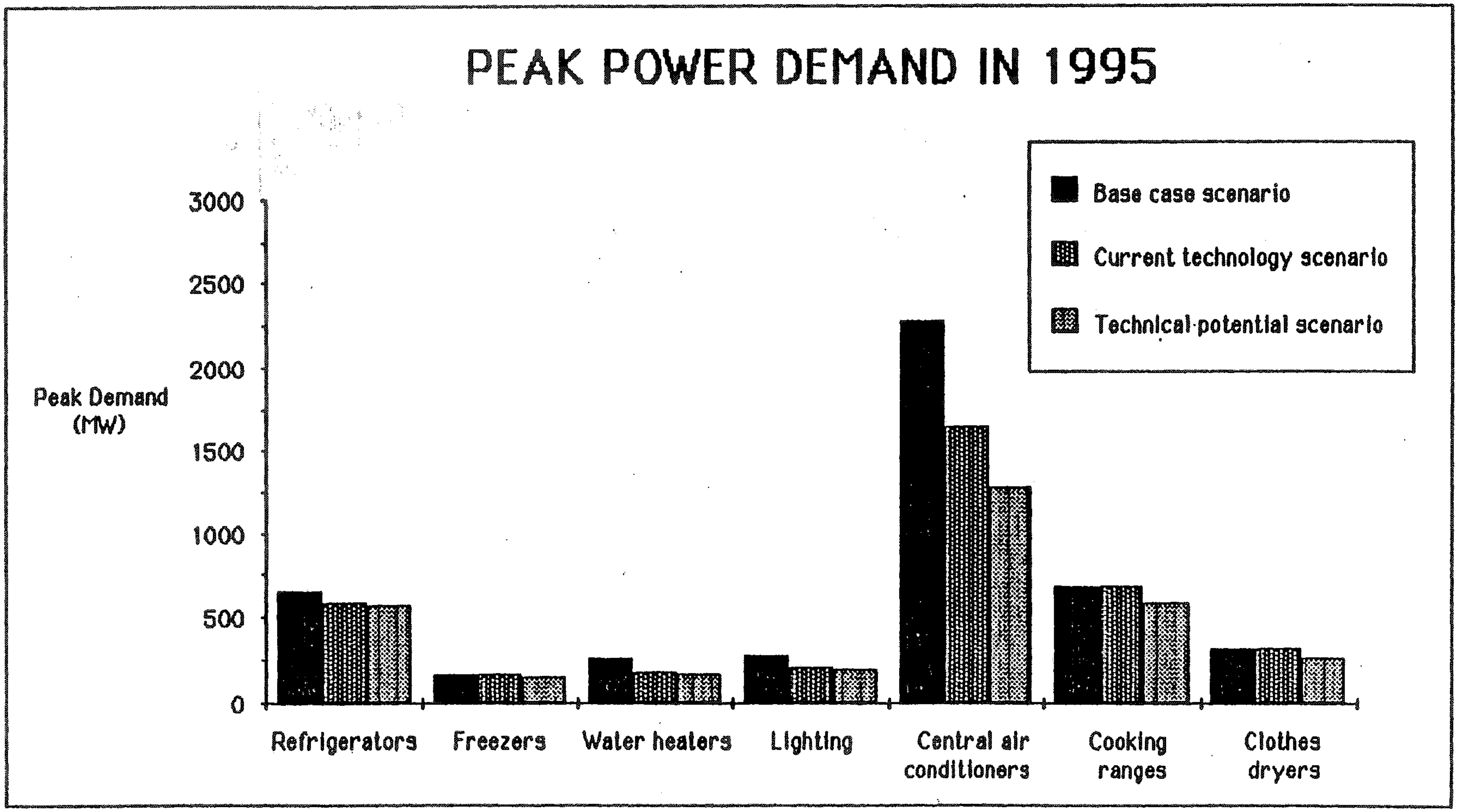
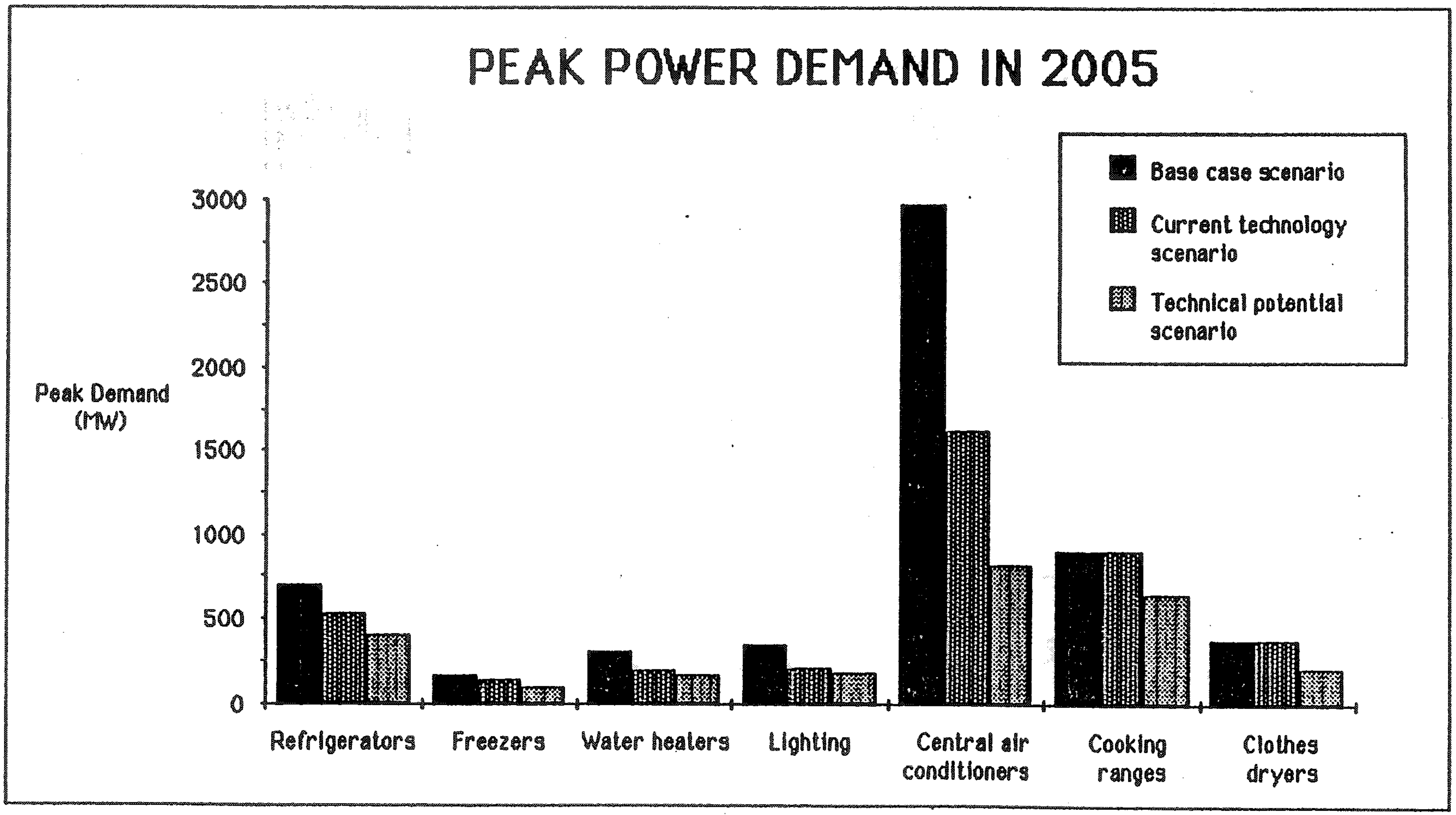

PEAK POWER DEMAND IN 1995
Peak Demand (MW)
3000
2500
2000
1500
1000
500
0
Base case scenario
Current technology scenario
Technical potential scenario
Refrigerators
Freezers
Water heaters
Lighting
Central air conditioners
Cooking ranges
Clothes dryers

Figure 6


PEAK POWER DEMAND IN 2005
Base case scenario
Current technology scenario
Technical potential scenario
Peak Demand (MW)
3000
2500
2000
1500
1000
500
0
Refrigerators
Freezers
Water heaters
Lighting
Central air conditioners
Cooking ranges
Clothes dryers

PART IV - QUALITATIVE ISSUES AND CONCLUSIONS

CHAPTER 11

OTHER CHARACTERISTICS OF A CONSERVATION POWER PLANT

The preceding technology assessments indicate that there is substantially more cost-effective conservation available than is currently incorporated in the PG&E's 1985 end-use model and long term planning results. The purpose of this chapter is to consider how a conservation power plant might compare with supply resources in areas other than technical potential and economics.

Thirteen different characteristics are discussed. The first nine:

- Small and modular plant size
- Short lead time
- Minimal capital/no AFUDC
- Reduced environmental risks
- Positive public relations
- Enhanced regulatory acceptance
- Increased load shape control
- Decreased dependence on oil and gas
- Reduced load forecast uncertainty

are covered in the section on factors that may decrease uncertainty. These provide support for the concept of relying on conservation.

The second section reviews four factors that may increase uncertainty:

- Technology performance and availability
- Implementation effectiveness
- Customer behavior
- Regulatory and political changes

There are significant unknowns associated with these four factors that must be taken seriously. However, at least some of the risks can be reduced through careful research, demonstration, monitoring and program design.

Many of the points in this section were made in PG&E's 1985 Generic Comparison of Technologies (Generation Planning Department), which calculates the comparative economics of 72 demand--side and supply-side resource alternatives. The report also evaluates a variety of other attributes of the alternative technologies including lead time, capital costs, AFUDC requirements, fuel diversity, and resource and regulatory constraints. In their comparison, conservation came out with high marks: "Conservation programs are our most efficient way of reducing revenue requirements. They rank high by all measures and have very short lead times."[1]

In addition, the report analyzed the risks associated with lead time, fuel diversity and project costs for each of the 72 technologies. Of all the alternatives, conservation and load management were determined to have the lowest risk.

We think it will be useful to review some of these less tangible benefits and risks as part of this initial report. No attempt has been made to be exhaustive or to quantify the impacts or relative weights.

A. Characteristics that may reduce uncertainty

Small and modular plant size

Changes in the PG&E's operating environment have increased the attractiveness of including small and modular resources in the resource mix. Uncertain economic growth, increased competition and a changing regulatory environment all contribute to substantial demand and economic uncertainty and create a need for planning flexibility.

The conservation opportunities described in this report offer extraordinary flexibility. Programs can be designed to "generate" more or less conservation, as desired. Conservation can be brought on line in stages, making it is easier to match demand requirements or respond to changes in the environment.

In fact, there may be a substantial economic premium to choosing small, modular resources. A recent study to determine the value to utilities of modular resources conducted for the Electric Power Research Institute states:

> "Using a new methodology for quantifying the benefits of modular power generation technologies, project analysts demonstrated that benefits such as short constructions lead times and small unit size can be significant. The results of this study indicate a value to ratepayers of $100-$300/kW, with higher values to shareholders."[2]

Moreover, modular conservation resources can help to decrease planning fluctuations. For example, prior to the commencement of Diablo Canyon and Helms operations, PG&E was supply constrained, marginal costs were higher than average costs, and electricity marketing was inappropriate. A year later with Diablo Canyon operating, PG&E now has the opposite situation. With excess capacity and marginal costs lower than average costs, electricity marketing is again encouraged. Digesting these enormous changes in direction and communicating their logic and impact to employees and customers requires substantial time, expense and effort. Conservation can help to avoid many of the problems inherent in such "lumpy" resource additions.

Short lead times

As lead times increase, so do the uncertainties surrounding a project. Will the demand be there when the plant is completed? Will intervening factors create delays and the significant cost overruns that are common with long construction periods? Cost overruns are particularly endemic in central generating stations and may result in massive price hikes that can eliminate the demand growth the project was constructed to fill.

Moreover, the possibility of regulatory disallowance of costs if a utility over-builds creates an asymmetrical treatment of planning error. It may be wiser for a utility to under-build and rely on resources with short lead times to accommodate demand variation rather than to be unable to recover costs.

Conservation and load management programs have the shortest lead times of all resource alternatives, according to the Generic Comparison of Technologies[3]. They estimate the lead time for a single (already tested) conservation program to be 1/2 year compared with 5.75 years for a gas turbine or 9.5 years for a small coal plant.[4]

Obviously, the lead time of a conservation power plant that consists of a series of programs (or a program that has not been previously tested) will depend upon the technologies used, the program designs, customer purchase behavior and the staff and budget available for implementation. Programs based upon existing technologies and tested program designs will have shorter lead times than programs that rely on products that are still in the prototype stage or on untested strategies. However, although longer lead times for advanced technologies or new strategies are necessary, relatively small amounts of RD&D capital will be required to develop and test them, limiting the company's financial exposure.

Minimal capital/no AFUDC

The capital intensity of a project is of paramount importance to PG&E because the CPUC does not allow funds used during construction (AFUDC) to be recovered until the plant is operating. Obviously, large plants place more money at risk than small plants. Moreover, regulatory capping of utility returns means that the utility cannot receive a higher return on larger, higher-risk ventures.

Conservation is particularly attractive because it is not capital intensive and can be leveraged to use other peoples' money. The costs of conservation programs can be immediately expensed as most programs are now and there would be no AFUDC exposure. Appliance dealers and manufacturers would likely bear the risk of producing and carrying the inventory of the technologies on which the conservation power plant is based. Moreover, programs could be designed so customers or lenders put up the bulk of capital, as in the current ZIP and rebate programs.

On the other hand, were PG&E to capitalize the cost of its investment in the conservation power plant, the capital exposure would be relatively small. The conservation power plant would be "used and useful" as soon as the first efficient refrigerator or air conditioner was plugged in, and, therefore, cost recovery and returns on investment could be available almost immediately.

Reduced environment risks

A conservation power plant avoids the environmental costs that result with more traditional power plants. Fossil-fired plants produce emissions of sulfur oxides, nitrogen oxides and particulates which cannot be 100% controlled. All fossil plants also create CO2. While not a hazardous pollutant in itself, increasing atmospheric levels of CO2 are believed to create a greenhouse effect causing a global warming that will melt the ice caps and raise ocean levels. A recent EPA study[5] predicted that the accumulation of carbon dioxide will cause global warming sufficient to flood 1.7 percent of California land with a loss of $13 billion in land value alone.

All thermal power plants, whether fossil or nuclear, create waste heat which must be dispersed. Water is generally used, leading to problems of water availability, cooling tower blowdown disposal, and thermal discharges into lakes and oceans. Lastly, many thermal plants generate solid or liquid wastes (radioactive waste, scrubber sludge, spent fuel) which have to be placed in appropriate, and often scarce, disposal or containment sites.

Clearly a conservation power plant compares favorably with these supply options in terms of environmental impacts. It would have none of the pollution and waste problems mentioned above and might even decrease the environmental risk of the whole system by reducing or shifting demand.

There has been some concern that environment hazards, such as indoor air pollution, are associated with conservation programs that tighten homes to reduce space conditioning costs. This is <u>not</u> an issue with the appliance-oriented electricity conservation measures proposed and evaluated in this report. Moreover, other utilities that have researched this issue have concluded that even weatherization programs do not subject customers to excessive health risks.[6]

If all environment impacts of power generation were accurately quantified and included in the benefit/cost analysis, conservation's economic advantage over fossil fuel, nuclear, and even co-generation would be even greater. In fact, other utilities are attempting to reflect these risks in their planning process. For example, the Northwest Power Planning Council assigns a 10% "environmental premium" to conservation when comparing it to traditional supply options. We understand that other California utilities are starting to make adjustments for such intangibles, also.

Positive public relations

PG&E serves 3.7 million residential customers who use one third of its total electric sales. These customers are very concerned about rate increases, and past experience indicates that they make their concerns known. Large, central station power plants can cause rate increases in large chunks, resulting in an unpleasant "rate shock" for customers. Moreover customers, because of their concern for environmental hazards, can contribute to the delays and cost overruns of large plants.

On the other hand, customers who have received conservation services such as audits and financing have a more positive perception of PG&E.[7] Furthermore, recent studies indicate that a large percentage of customers think that PG&E should continue to provide conservation services.[8]

Pursuing a conservation power plant would give PG&E many opportunities to join forces with its residential customers to save energy and reduce electric costs. Every home that participated in a conservation program might have a sticker on their refrigerator or other efficient appliance saying "I'm helping to build a conservation power plant". It would allow opportunities to work with communities and community groups from whom PG&E could purchase "conservation energy" through activities like the Community Energy Management Program.

A conservation power plant would also give customers more control over their bills. Customers could actively participate in the power plant by purchasing and using efficient appliances, and thereby reduce their energy consumption, offset high rates and rate increases, and keep total energy bills down. By increasing customer control, the conservation power plant could help to decrease high bill complaints and make the relationship between the company and its customers less adversarial.

Enhanced regulatory acceptance

If PG&E wants to build an in-state power plant, it must go through a certificate procedure at both the California Energy Commission (CEC) and the California Public Utility Commission (CPUC). It must invest time and money in exploring different sites and alternatives to the plant. The lead time to get permission to build is more than three years, usually followed by a multi-year construction period that exposes the Company to the risks of delays and cost overruns discussed previously.

If, for some reason, the plant is never completed (perhaps because of a fall in demand) it is an open question whether the utility will recover its costs. Even if it is completed, the utility cannot be sure how much of the costs it will recover until an often long and gruelling prudence review is completed.

On the other hand, approval of expenditures for conservation programs traditionally comes in a rate case covering funds to be spent in the next 2-3 years. The benefit-cost ratios for the project can be estimated over a reasonable time frame. This avoids some of the uncertainty problems inherent in most supply projects. Another advantage is that the funds are approved in advance in a rate case. While the CPUC may subsequently question PG&E's implementation of a conservation program, changes in authorized funding levels usually affect future programs rather than penalizing past decisions. This, again, reduces the financial exposure of the company.

As an alternative to the rate case approach, PG&E might consider the unconventional approach of filing a certificate application for its conservation power plant, explicitly treating conservation as an alternative source of supply. The company could "rate base" some of the costs and earn a return on its investment. This approach might offer more flexibility than rate cases. It would provide a basis for planning and gaining approval for conservation programs that the PG&E wants to implement at some point in the future, when demand requires it, but later than the current rate case may cover.

Lastly, the CPUC has published a series of policy statements in its opinions directing utilities to treat conservation like supply and to pursue it when more cost-effective. The CEC, also, has given conservation and load management programs preference over conventional generation technologies.[9] A conservation power plant would be directly responsive to these commissions' statements and can be characterized as such.

Increased control over load shape

A conservation power plant consisting of strategically designed conservation and load management programs and supported by appropriate rate signals could provide PG&E with greater control over its load shape. For example, many of the end uses covered in this report contribute heavily to peak load. By substituting the more efficient technologies described, the total energy use will be decreased, also decreasing peak usage. Any improvement in the efficiency of air conditioners, for instance, will automatically improve load shape, reducing the peak to average ratio.

In addition, many residential appliances can be run off-peak (laundry equipment, electric water heaters, ranges) although there is currently little incentive for residential customers to do so. The presence of time-varying rates (time of use or spot-priced) could stimulate and reward behavioral changes. With such rates available, the time of use of appliances could be changed voluntarily by customers, through conventional utility-controlled cycling devices, or through customer-programmed interrupt technologies.

Decreased dependence on oil and gas:

According to the Generic Comparison of Technologies[10], PG&E's large yearly generation in oil/gas fired units combined with the high cost of those fuels makes PG&E dependent on their future price, availability and security. Resources that decrease the company's use of oil and gas or increase fuel diversity are considered attractive.

Since conservation does not require any fuel (in fact, may reduce oil/gas consumption), a conservation power plant would decrease the Company's overall risk associated with oil and gas dependence.

Reduced load forecast uncertainty

Another possible benefit of conservation lies in its ability to reduce the amount of uncertainty in demand forecasts. This concept was proposed by the National Resources Defense Council in their testimony before the CPUC[11]. They suggest that demand uncertainty arises in part from a spread in probable economic growth rates: higher economic growth means more appliances, buildings, etc., and more energy use, while less growth leads to proportionally less new energy demand. Conservation may lessen the uncertainty by decreasing the ratio of new energy consumption to new economic activity. If all new homes are highly efficient, then the impact on a utility of underestimating economic growth in absolute terms is lower then if the new demand came on line with a higher consumption per household. Thus, conservation may reduce the uncertainty in future demand for a given uncertainty in future economic activity.

Conservation and load management programs may decrease uncertainty related to the variability of energy use in the existing system as well. This would limit the spread in predictions of energy consumption that occurs without conservation programs. Today there is a very wide range of efficiencies and energy consumption levels available with new refrigerators, air conditioners and other appliances. PG&E can only guess at how the market will respond to the energy conserving opportunities in the next 20 years. But, if PG&E were to vigorously encourage the purchase of efficient products, there will be less uncertainty regarding the average efficiencies in the future, and thus better accuracy in end-use forecasting.

B. Characteristics that may increase uncertainty

On the other hand, there are substantial questions associated with a heavy reliance on residential electricity conservation. Will the technologies perform as expected? Will the savings be available when needed? Will the penetration be as great as predicted?

This section reviews four issues: the performance of the technologies; the effectiveness of program implementation; customers behavior; and changes in regulatory climate. Each of these issues will affect the predictability of demand reduction from a conservation power plant and will require further careful research if the concept is to succeed.

Technology Performance and Availability

The first concern is whether the technology will be available. Many of the technologies discussed in this report are already commercially produced and widely used. In fact, the majority of the potential relies on existing technologies that are readily available, fully-tested and have well-quantified benefits, but are not yet widely used.

However, with the more advanced technologies there is much greater uncertainty. The technologies are primarily in the prototype stage and field testing will be needed to verify their performance. Moreover, there is substantial uncertainty about when (or if) manufacturers will begin producing these appliances and whether sufficient trained installers will be available.

Because of its large size, PG&E might have some control over this situation. It may be able to stimulate the production of new technologies by offering incentives to manufacturers such as committing to provide rebates in the future. Or, perhaps, if it chose, PG&E could import, distribute or even produce super-efficient appliances themselves, through a subsidiary, partnership, or licensing arrangement.

A second area of concern is whether a technology will actually deliver the predicted savings. The consumption values used in this report for commercially available technologies are based on monitored field tests and are generally reliable. The savings in any particular household may be greater than or less than what is stated here. But the average savings, which is what concerns PG&E, should be close to what is claimed.

However, for new, non-commercial technologies, a careful program of research and development and periodic testing by PG&E itself, by an independent testing laboratory, or in conjunction with manufacturers will be essential to reduce the performance uncertainty. Uncertainty about the performance of advanced technologies will decline as they are commercialized and used.

We think it is in PG&E's interest to proceed with the research and development of the new technologies, so that they will be ready for program implementation. The earlier the work is done, the better the technology will be understood, and the more robust PG&E's set of contingency resources will be.

Finally, there is some concern that savings may decay over time because of poor maintenance of equipment or changes in operating conditions. PG&E is already embarking on an on-site analysis of equipment efficiencies to improve its understanding of these issues[12].

In any case, the performance of technologies will have to be carefully monitored and planning calculations, such as benefit/cost ratios, will have to adjusted as better information is available. The fact that the programs can be easily adjusted as experience is refined is another benefit of the conservation power plant.

Implementation effectiveness

A second area which can affect the accuracy of savings estimates is the effectiveness of program implementation. Clearly not all of the savings identified in the technical potential scenarios can be achieved. If PG&E decides to further evaluate a conservation power plant, it will have to make some assumptions about the expected level of penetration of technologies in response to marketing and incentive efforts to get a better idea of the realizable size of the plant. This is discussed in the next chapter.

Market penetration is dependent upon a series of factors including price (rebate levels, rate structure), promotion (advertising, sales force), effectiveness and credibility of distribution channels[13], and the product itself. PG&E already has valuable experience in program design and implementation. Using well-planned pilot-tests with market research and evaluation components will help further refine its ability to create and operate programs in the most cost-effective way to obtain the desired results. We should note that these tests are most appropriately done before the resource is needed so that the technology and program design can be fine-tuned. There is the opportunity to do this now when supply is not constrained and avoid potentially higher costs of "crisis response" in the future.

EPRI's current project on customer behavior and attitude may provide insight into determining the amount of incentives or promotion required to achieve a certain level of market penetration. In addition, many other utilities are testing appliance programs and their experience will help PG&E pinpoint how to design effective incentives to generate the level of response desired.

Measurement is an important part of implementation effectiveness. Keeping close tabs on how the average efficiency of new purchases evolves over time will enable PG&E to understand the level of conservation that is occurring. Sales of the various efficient appliances will give a general indication of how the conservation power plant is progressing. Program design and savings estimates can be refined as information is obtained.

Customer behavior

Customer behavior may affect the predictability of demand reduction from conservation or load management programs. The first risk is one of re-spending, or what economists call the "income effect". Theoretically, conservation will result in lower utility bills. The income freed up may be used to buy goods which result in more electricity use (e.g. extra appliances and home entertainment equipment), or may justify raising the thermostat or buying an air conditioner. This issue is important and not well understood. On-going behavioral studies and market research on the use of discretionary income will be necessary to identify the likely impacts.

A second concern is that customers may inhibit the effectiveness of installed technologies. They may remove low-flow showerheads, change the setting on the water heater, or neglect their air conditioner filter. Much of this can be accounted for by incorporating actual customer use data and behavioral studies into saving estimates and by focusing on conservation measures where there is less likelihood of behavior variation.

There is also justifiable concern that utility incentive programs provide unnecessary subsidies to those who would have bought an efficient model anyway. These redundant subsidies should be taken into account when evaluating the actual savings and cost-effectiveness of a program. The important issue is whether or not a program is attractive compared to other supply options when redundant subsidies are considered. We believe it is entirely possible to design programs that are economical and that minimize unnecessary incentives. For example, incentives could be restricted to new, super-efficient models, or to only the extra first cost of the more efficient appliance.

Finally, there is an continuing concern about equity -- that non-participants will be penalized by the costs of a conservation program. A non-participant test (also known as the "no-losers test") requires that rates do not increase. Some utilities use it to evaluate their conservation programs, but it is a more stringent assessment than is used for any other resource option. Moreover, intangibles such as environmental degradation and increased risks associated with traditional supply that can affect all ratepayers are not factored into the equation. Other planning agencies[14] have rejected the non-participant test and we hope that PG&E and its regulators will do the same.

Regulatory and Political changes

As utilities are more directly involved in conservation, they are becoming increasingly competitive with existing businesses. Manufacturers, dealers and installers are concerned that utilities have an unfair marketing advantage and are seeking to limit utility activities through legislation and regulation. For example, legislation in California prohibits PG&E from performing contracting work on non-utility property, except for utility functions (generation, transmission or distribution of electricity, gas, water or steam). The utility is allowed to work only "up to the meter" of a building.

Moreover, the signals coming from PG&E's regulators about conservation are becoming less clear. Conservation may not continue to receive the regulatory support it has in the past from either the CPUC or the CEC.

The impact of these and other changes in the political environment is extremely uncertain. They have the potential to severely limit the program design and implementation options available for the conservation power plant. For example, PG&E might be prohibited from offering appliance installation and maintenance services. Or, on the other hand, regulators might require that all conservation programs be offered to all ratepayers, rather than just to cost-effective segments. It is unclear whether a conservation power plant would experience more or less political penalties than other resources would.

There are some factors that may mitigate against the adverse effects of these changes. For example, PG&E's long standing relationship with its trade allies through the Electric and Gas Industries Association and the more recent Contractors Advisory Group have shown that programs can be designed to benefit all parties. Also, because conservation is flexible and has a short lead time, programs can changed more rapidly in response to a changing regulatory climate than can most other resources.

C. Summary:

Considering the broad range of issues discussed here, a conservation power plant appears to offer an attractive, strategic, contingency resource for PG&E. In comparison to supply options, it has the shortest lead times, the lowest risk of environmental degradation, no AFUDC exposure, maximum flexibility, and decreased dependence on oil and gas. It is less likely to experience regulatory delays and has the potential to improve the Company's relations with its customers. A well-designed set of conservation and load management programs can offer increased control over the load shape and decreased load uncertainty. No other resource option can provide all of these benefits.

The uncertainties associated with the effectiveness of a conservation power plant relate primarily to the uncertainties in technologies, implementation, customer response and unexpected changes in the regulatory and political environment. These uncertainties may be problematic. However, we believe that they can be managed and limited through a well-planned program of research, development and demonstration. This program would be relatively inexpensive in comparison to the capital commitment required for a central station power plant. It should be started immediately to provide the most robust set of resource options for the company.

In the next chapter, we suggest a series of next steps that PG&E should take to proceed to evaluate and develop a conservation power plant.

References

1. Katz, Michael, 1985 Generic Comparison of Technologies (GCT). PG&E Generation Planning Department, August 1985, page 1-6. The 1983 and 1985 reports both show conservation and load management to have 10 of the top 12 benefit/cost ratios among the 72 technologies considered.

2. Electric Power Research Institute, Impact of Modularity on Utility Investment Decisions: Implications for Turbocharged Boiler Technologies, EPRI EA/CA-4158, September 1985, p. 1.

3. Katz, Table 4-3 "Imput for Generic Comparisons", pages 4-4 to 4-8.

4. Katz, Chapter 6.

5. Seidel, S: Can We Delay a Greenhouse Warming?: U.S. Environmental Protection Agency; Washington, D.C.: September 1983.

6. "The Expanded Residential Weatherization Program: Final Environmental Impact Statement", Bonneville Power Administration, Agugst 1984.

7. "ZIP Follow-up Study", Marylander Marketing Research, Inc., March 1983.

8. Kathy Hyams, Corporate Communications; Value of Service Study, 1985; RCS Advisory Council Hearings, 1984.

9. California Energy Commission, 1981 Biennial Report.

10. Katz, page 6-5.

11.Miller, Peter M., and Goldstein, David B.; Testimony of the Natural Resources Defense Council, Inc. before the California Public Utilities Commission; March 25-26, 1985.

12. Barbara Baldridge, Economics and Forecasting, is organizing an on-site survey to measure appliance efficiency. In addition, according to Les Guiliasi, the Rate Department has an on-going program of on-site appliance testing.

13. In its previous home weatherization programs, PG&E has found that the quality of install ation has been a major issue. However, for the majority of the appliances described in this report, installation is comparatively simply, and therefore less of a concern.

CONCLUSION AND NEXT STEPS

A. Conclusion

The technical and economic potential for electricity savings in PG&E's residential sector is enormous. Considering only technologies now commercially available (along with slight additional savings due to the new state minimum efficiency standards), we estimate a potential reduction in electricity consumption of 5180 GWh/yr and a potential reduction in peak summer demand of 1790 MW by the year 2005 (see Chapter 10). Allowing for the commercialization and phase-in of advanced technologies that appear to be cost-effective and technically achievable, the potential savings increases to 9260 GWh/yr and 3240 MW of peak summer demand by 2005.

These savings estimates do not include any changes in equipment saturation or appliance retirement. Of course, shifting to some extent from electrical to gas equipment or encouraging a more rapid turnover in the appliance stock could further increase the savings potential.

On the other hand, the estimates of savings potential are based on rapid shifts to more-efficient new appliances on a massive scale. The estimates of savings potential do not take into account any of the limitations inhibiting high levels of implementation. In reality, it is unlikely that the full technical and economic potential can be be achieved.

All of the energy savings options included in the current technology and technical potential scenarios appear to be cost-effective relative to PG&E's marginal energy and/or peak capacity costs. This judgement is based on the estimated extra first cost for the options, along with economic assumptions consistent with utility financing. No attempt was made to estimate and include program costs or other costs associated with obtaining the indicated savings.

We also have not attempted to estimate the total first cost or cost of saved energy and peak power associated with the conservation power plant at this stage. This is due to the complexities introduced by including a large number of options with differing lifetimes and penetration rates relative to the base case scenario. It is felt that it would be more reasonable to estimate overall cost and cost-effectiveness once a conservation power plant is better defined.

It should be recognized that many of the energy savings measures for important end-uses such as refrigerators and lighting appear to be very cost-effective (i.e., with a cost of saved energy that is less than $0.05/kWh, and in some cases less than $0.02/kWh). This suggests that an overall conservation power plant could be considerably less expensive than alternative energy supply resources. Even though PG&E does not need large amounts of new energy supply facilities during the next 20 years, energy efficiency improvements in the areas examined are more economical than even small additions of new generating capacity.

The discussion in Chapter 11 concerning the qualitative characteristics of a conservation power plant indicates that there are many other advantages to PG&E vigorously pursuing end-use efficiency as a resource option. These include short lead time, high flexibility, technological diversity, and favorable environmental impacts. On the other hand, there are significant uncertainties related to implementation, utility involvement, and customer response. But, through comprehensive technical analysis as well as program experimentation and evaluation, we believe it should be possible to limit these uncertainties to manageable levels.

The development and implementation of a strategy to obtain many hundreds of MWs and thousands of GWhs of electricity savings is no doubt a complicated, multi-stage process (as is the construction of equivalent generating capacity). We hope this assessment of the potential components and size of a conservation power plant is a useful first step in that process.

The concept of designing and implementing a conservation power plant presents PG&E with a tremendous opportunity for minimizing the cost of energy services among its customers, as well as for providing other benefits. At the same time, a well-supported, long-term and strategic commitment to increasing end-use efficiency is something new for PG&E and other utilities. By building a conservation power plant, PG&E can not only better serve its own customers, but can also lead the way within the rapidly changing utility industry.

B. Next Steps

We recommend that a number of activities be undertaken to further the process of evaluating and developing the conservation power plant. The order of the following recommendations is not meant to indicate priority or importance.

1. Continue to develop scenarios

Now that the full technical and economic savings potential has been estimated, it would be useful to develop one or more "implementation-constrained" scenarios. To develop these new scenarios, assumptions are needed regarding which technology options to include, the level of penetration that can be achieved, and the timing of implementation.

The assumptions needed for an implementation-constrained analysis could be generated by examining previous programs conducted by PG&E to promote, finance, and provide incentives for energy-efficient appliances and residential electricity conservation in general. This experience should be reviewed with the objective of defining what could be achieved in new efforts that are strategically designed, well-funded and supported, and aggressively pursued.

Now that a computer program has been developed for conducting the scenarios analysis, it is straightforward to produce additional scenarios by adopting new assumptions regarding new product efficiencies and other factors.

Besides generating such scenarios, it would be useful to further refine the computer program itself. This could include adding the costs for energy conservation into the scenarios analysis, integrating the technology assessments and scenarios analysis within the computer program, and adding a provision for including conservation program costs as part of the analyses.

2. <u>Begin to assess program options</u>

The realization of large electricity savings in the residential sector will require a host of well-designed and skillfully implemented programs. Program options should be carefully studied, including issues such as potential costs, potential savings and other benefits, and institutional obstacles.

Programs involving a continuation or expansion of past activities should of course be considered. This includes conventional residential rebate and financing programs. Also, new program options should be investigated, including:

a) Marketing, financing and installation efforts conducted solely by PG&E or together with trade allies such as appliance dealers or HVAC contractors;

b) The creation of a subsidiary to manufacture, import, or distribute very efficient appliances;

c) Programs involving equipment rental or leasing;

d) Residential shared savings or pay-for-savings programs;

e) Incentive programs targeted at the parties that play an important role in equipment selection (appliance dealers, landlords, or AC and plumbing contractors);

f) Programs to stimulate the commercialization of new, highly efficient end-use technologies.

In reviewing previous program experience and thinking about new programs, attention should be given to the issue of the "reliability" of the savings and penetration estimates. Acknowledging major uncertainties could lead to suggestions for new program evaluations and program experiments that could help to better define the likely impacts from large-scale programs.

3. Analyze potential R&D activities

Many technology-oriented R&D projects were recommended at the end of each technology assessment. These project ideas need to be further studied, including the development of project outlines and objectives, time requirements, and funding requirements. Then it would be useful to generate a list of high-priority projects and a multi-year R&D plan.

Technology R&D efforts ideally should be linked to the commercialization and implementation of important electricity conservation measures, i.e., focusing on technologies that are logical elements of a conservation power plant. It should be easier to develop this linkage once conservation strategies are better defined.

4. <u>Evaluate intra-utility and regulatory issues</u>

It is likely that initiating and successfully "building" a conservation power plant will require favorable decisions from within PG&E and from the utility commission. It may be useful to consider at an early stage the obstacles (if any) to such an effort in PG&E and the CPUC, and how they might be overcome.

Some of the issues to consider include:

a) How is conservation investment and promotion viewed within the company? What needs to be demonstrated in order to proceed with such an endeavor?

b) What are the legal and regulatory constraints to the broad effort as well as specific programs and activities? How might these constraints be overcome?

c) What are the funding and financing options and constraints and how would they impact the company?

Pursuing a conservation power plant will also effect revenue requirements, rates, and other financial considerations within PG&E. Once the direct costs and other effects of the endeavor are better defined, these impacts should be analyzed.

APPENDIX A

WORKSHEETS FOR THE BASE CASE SCENARIO

Table A-1

PG&E Conservation Power Plant Study
Standard Refrigerator Analysis
Base Case Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	715	712	1427	63	53	695	830	1134	795	106	151
1986	717	721	1438	64	53	695	830	1135	789	105	151
1987	719	729	1448	63	53	695	830	1134	783	104	151
1988	721	737	1458	63	54	580	810	1127	773	103	150
1989	723	744	1467	63	54	580	810	1120	763	102	149
1990	725	752	1477	64	54	580	805	1113	754	100	148
1991	727	761	1488	65	55	580	800	1107	744	99	148
1992	731	771	1502	69	55	436	780	1094	729	97	146
1993	734	781	1515	68	56	436	780	1081	713	95	144
1994	738	792	1530	71	56	436	770	1068	698	93	142
1995	742	804	1546	72	57	436	760	1056	683	91	141
1996	747	817	1564	75	58	436	760	1045	668	89	139
1997	752	830	1582	76	58	436	750	1034	654	87	138
1998	756	844	1600	76	59	436	740	1024	640	85	136
1999	761	858	1619	78	60	436	730	1014	627	83	135
2000	766	872	1638	79	60	436	725	1005	614	82	134
2001	770	884	1654	76	61	436	715	995	601	80	133
2002	776	894	1670	77	62	436	710	985	590	79	131
2003	781	904	1685	77	62	436	700	975	578	77	130
2004	787	914	1701	78	63	436	695	965	567	76	129
2005	792	924	1716	78	63	436	690	955	557	74	127

Table A-2

PG&E Conservation Power Plant Study
Frost-Free Refrigerator Analysis
Base Case Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	2089	678	2767	165	102	1127	1345	3567	1289	172	475
1986	2136	698	2834	169	104	1120	1345	3615	1276	170	482
1987	2183	719	2902	172	107	1070	1345	3656	1260	168	487
1988	2228	739	2967	172	109	1020	1300	3689	1243	166	491
1989	2268	757	3025	167	111	1020	1300	3715	1228	164	495
1990	2307	776	3083	169	114	1020	1300	3740	1213	162	498
1991	2351	795	3146	177	116	1020	1300	3770	1198	160	502
1992	2399	817	3216	186	118	950	1260	3797	1181	157	506
1993	2448	839	3287	189	121	950	1250	3826	1164	155	510
1994	2496	861	3357	191	124	950	1250	3853	1148	153	513
1995	2550	883	3433	200	126	950	1240	3886	1132	151	518
1996	2604	908	3512	205	129	950	1240	3920	1116	149	522
1997	2662	932	3594	211	132	950	1230	3958	1101	147	527
1998	2717	957	3674	212	135	950	1225	3994	1087	145	532
1999	2773	982	3755	216	138	950	1215	4032	1074	143	537
2000	2833	1008	3841	224	142	950	1210	4074	1061	141	543
2001	2890	1035	3925	226	145	950	1205	4114	1048	140	548
2002	2952	1061	4013	233	148	950	1190	4159	1036	138	554
2003	3014	1085	4099	234	151	950	1180	4203	1025	137	560
2004	3080	1111	4191	243	154	950	1170	4253	1015	135	567
2005	3143	1136	4279	242	158	950	1165	4299	1005	134	573

Table A-3

PG&E Conservation Power Plant Study
Standard Freezer Analysis
Base Case Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	691	158	849	45	28	750	910	688	810	107	91
1986	705	162	867	46	29	725	905	695	802	106	92
1987	719	166	885	47	29	700	905	701	792	104	92
1988	732	170	902	46	30	650	900	704	781	103	93
1989	744	174	918	46	31	600	900	705	767	101	93
1990	756	177	933	46	31	550	895	702	752	99	92
1991	768	181	949	47	32	500	880	697	735	97	92
1992	783	186	969	52	32	484	875	694	716	94	91
1993	797	190	987	50	33	484	870	690	699	92	91
1994	812	194	1006	52	34	484	865	686	682	90	90
1995	828	199	1027	55	34	484	860	683	665	88	90
1996	845	205	1050	57	35	484	855	681	648	85	90
1997	862	210	1072	57	36	484	850	678	632	83	89
1998	879	216	1095	59	36	484	845	676	617	81	89
1999	896	221	1117	58	37	484	840	673	602	79	89
2000	913	227	1140	60	38	484	835	670	588	77	88
2001	930	232	1162	60	39	484	830	667	574	76	88
2002	949	237	1186	63	40	484	825	665	560	74	88
2003	968	242	1210	64	40	484	820	662	547	72	87
2004	988	246	1234	64	41	484	810	660	535	70	87
2005	1007	251	1258	65	42	484	800	658	523	69	87

Table A-4

PG&E Conservation Power Plant Study
Frost-Free Freezer Analysis
Base Case Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	270	56	326	18	11	1137	1900	582	1785	235	77
1986	276	58	334	19	11	1137	1890	582	1743	230	77
1987	281	59	340	17	11	1137	1880	580	1707	225	76
1988	286	61	347	18	12	1137	1870	580	1671	220	76
1989	291	62	353	18	12	1137	1860	578	1637	216	76
1990	295	63	358	17	12	1137	1850	575	1606	212	76
1991	300	65	365	19	12	1137	1840	574	1572	207	76
1992	306	66	372	19	12	1137	1830	573	1540	203	75
1993	312	68	380	20	13	1137	1820	573	1508	199	76
1994	317	69	386	19	13	1137	1810	571	1480	195	75
1995	324	71	395	22	13	1137	1800	572	1449	191	75
1996	330	73	403	21	13	1137	1780	572	1420	187	75
1997	337	75	412	22	14	1137	1760	574	1393	183	76
1998	343	77	420	22	14	1137	1740	574	1367	180	76
1999	350	79	429	23	14	1137	1720	576	1342	177	76
2000	357	81	438	23	15	1137	1700	577	1318	174	76
2001	364	82	446	23	15	1137	1680	578	1296	171	76
2002	371	84	455	24	15	1137	1660	580	1275	168	76
2003	378	86	464	24	15	1137	1640	582	1255	165	77
2004	386	87	473	24	16	1137	1620	584	1236	163	77
2005	393	89	482	25	16	1137	1600	587	1218	160	77

Table A-5

PG&E Conservation Power Plant Study
Electric Water Heater Analysis
Single Family Housing
Base Case Scenario

Year	SF Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	300	32	18	4030	4400	1320	4400	544	163
1986	315	33	18	4030	4400	1374	4361	539	170
1987	329	33	19	3870	4400	1418	4309	533	175
1988	344	35	20	3870	4300	1467	4265	527	181
1989	357	34	21	3590	4300	1499	4199	519	185
1990	370	35	22	3590	4300	1530	4136	511	189
1991	384	36	22	3450	4200	1562	4067	503	193
1992	399	38	23	3450	4200	1596	4000	495	197
1993	415	40	24	3450	4200	1633	3935	487	202
1994	430	40	25	3450	4100	1669	3880	480	206
1995	447	43	26	3450	4100	1710	3826	473	211
1996	464	44	27	2980	4100	1731	3730	461	214
1997	485	49	28	2980	4030	1764	3636	450	218
1998	503	47	29	2980	4030	1786	3551	439	221
1999	522	49	30	2030	3870	1769	3389	419	219
2000	538	47	31	2030	3870	1744	3241	401	216
2001	558	53	33	2030	3590	1733	3107	384	214
2002	578	54	34	2030	3590	1721	2978	368	213
2003	600	57	35	2030	3450	1716	2861	354	212
2004	621	57	36	2030	3450	1708	2750	340	211
2005	643	60	38	2030	3450	1699	2642	327	210

Table A-6

PG&E Conservation Power Plant Study
Electric Water Heater Analysis
Multi-Family and Mobile Housing
Base Case Scenario

Year	SF Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	105	32	6	2500	3000	294	2800	346	36
1986	112	14	7	2500	3000	308	2752	340	38
1987	118	13	7	2500	3000	320	2710	335	40
1988	124	13	7	2500	3000	331	2671	330	41
1989	129	13	8	2120	3000	335	2598	321	41
1990	134	13	8	2120	3000	339	2529	313	42
1991	140	14	8	2120	2900	345	2466	305	43
1992	146	15	9	2120	2800	352	2412	298	44
1993	152	15	9	2120	2700	360	2367	293	44
1994	160	17	9	2120	2650	372	2323	287	46
1995	167	17	10	2120	2600	382	2287	283	47
1996	175	18	10	1810	2550	389	2222	275	48
1997	183	19	11	1810	2500	396	2164	267	49
1998	191	19	11	1810	2500	403	2109	261	50
1999	200	21	12	1810	2500	411	2055	254	51
2000	208	20	12	1810	2500	417	2005	248	52
2001	216	21	13	1810	2120	428	1980	245	53
2002	221	18	13	1810	2120	433	1958	242	53
2003	229	21	13	1810	2120	443	1935	239	55
2004	236	21	14	1810	2120	451	1913	236	56
2005	243	21	14	1810	2120	460	1892	234	57

Table A-7

PG&E Conservation Power Plant Study
Lighting Analysis
Base Case Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	UEC Stock (kWh)	Total Usage (GWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	2288	1309	3597	1000	3597	64	230
1986	2335	1342	3677	1000	3677	64	235
1987	2381	1375	3756	1000	3756	64	241
1988	2424	1406	3830	1000	3830	64	245
1989	2462	1434	3896	1000	3896	64	250
1990	2502	1464	3966	1000	3966	64	254
1991	2544	1494	4038	1000	4038	64	259
1992	2593	1529	4122	1000	4122	64	264
1993	2640	1564	4204	1000	4204	64	269
1994	2690	1600	4290	1000	4290	64	275
1995	2742	1638	4380	1000	4380	64	281
1996	2797	1678	4475	1000	4475	64	287
1997	2853	1719	4572	1000	4572	64	293
1998	2909	1761	4670	1000	4670	64	299
1999	2966	1802	4768	1000	4768	64	305
2000	3023	1845	4868	1000	4868	64	312
2001	3081	1888	4969	1000	4969	64	318
2002	3143	1927	5070	1000	5070	64	325
2003	3207	1965	5172	1000	5172	64	331
2004	3270	2004	5274	1000	5274	64	338
2005	3333	2043	5376	1000	5376	64	344

Table A-8

PG&E Conservation Power Plant Study
CAC Analysis - Zone 1
Base Case Scenario

Year	Total units (1000)	New units (1000)	Retire units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	41.80	5.35	2.09	840	976	32.50	778	1473	62
1986	45.40	5.87	2.27	840	976	35.22	776	1470	67
1987	49.00	6.05	2.45	840	976	37.91	774	1466	72
1988	52.60	6.23	2.63	840	950	40.64	773	1464	77
1989	56.20	6.41	2.81	840	950	43.36	771	1462	82
1990	59.80	6.59	2.99	840	950	46.05	770	1459	87
1991	63.40	6.77	3.17	840	925	48.81	770	1459	92
1992	67.00	6.95	3.35	840	925	51.54	769	1458	98
1993	70.60	7.13	3.53	840	925	54.27	769	1457	103
1994	74.20	7.31	3.71	840	960	56.85	766	1452	108
1995	77.80	7.49	3.89	840	935	59.50	765	1449	113
1996	81.40	7.67	4.07	750	935	61.45	755	1431	116
1997	85.00	7.85	4.25	750	935	63.36	745	1413	120
1998	88.60	8.03	4.43	750	900	65.40	738	1399	124
1999	92.20	8.21	4.61	750	900	67.41	731	1385	128
2000	95.80	8.39	4.79	700	850	69.21	722	1369	131
2001	99.40	8.57	4.97	700	850	70.98	714	1353	135
2002	103.00	8.75	5.15	700	850	72.73	706	1338	138
2003	106.60	8.93	5.33	650	850	74.00	694	1316	140
2004	110.20	9.11	5.51	650	850	75.24	683	1294	143
2005	113.80	9.29	5.69	650	850	76.44	672	1273	145

Table A-9

PG&E Conservation Power Plant Study
CAC Analysis - Zone 2
Base Case Scenario

Year	Total units (1000)	New units (1000)	Retire units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	162.40	17.00	8.12	950	1250	147.00	905	1715	279
1986	171.40	17.57	8.57	950	1250	152.98	893	1691	290
1987	180.40	18.02	9.02	950	1250	158.82	880	1668	301
1988	189.40	18.47	9.47	950	1250	164.53	869	1646	312
1989	198.40	18.92	9.92	950	1250	170.11	857	1625	322
1990	207.40	19.37	10.37	950	1250	175.55	846	1604	333
1991	216.40	19.82	10.82	950	1250	180.85	836	1584	343
1992	225.40	20.27	11.27	950	1200	186.58	828	1569	354
1993	234.40	20.72	11.72	950	1200	192.20	820	1554	364
1994	243.40	21.17	12.17	950	1100	198.93	817	1549	377
1995	252.40	21.62	12.62	950	1100	205.58	815	1543	390
1996	263.40	24.17	13.17	750	1000	210.54	799	1515	399
1997	274.40	24.72	13.72	750	1000	215.36	785	1487	408
1998	285.40	25.27	14.27	750	1000	220.04	771	1461	417
1999	296.40	25.82	14.82	750	900	226.07	763	1445	428
2000	307.40	26.37	15.37	700	900	230.70	750	1422	437
2001	318.40	26.92	15.92	700	850	236.01	741	1405	447
2002	329.40	27.47	16.47	700	850	241.24	732	1388	457
2003	340.40	28.02	17.02	650	850	244.98	720	1364	464
2004	353.00	30.25	17.65	650	850	249.64	707	1340	473
2005	365.00	30.25	18.25	650	850	253.79	695	1318	481

Table A-10

PG&E Conservation Power Plant Study
CAC Analysis - Zone 3
Base Case Scenario

Year	Total units (1000)	New units (1000)	Retire units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	361.00	31.20	18.05	1400	1800	523.00	1449	2745	991
1986	374.72	32.45	18.74	1400	1800	534.71	1427	2704	1013
1987	388.96	33.69	19.45	1400	1800	546.87	1406	2664	1036
1988	403.74	34.97	20.19	1400	1700	561.50	1391	2635	1064
1989	419.08	36.30	20.95	1400	1700	576.70	1376	2608	1093
1990	435.00	37.68	21.75	1400	1700	592.47	1362	2581	1123
1991	451.53	39.11	22.58	1400	1700	608.83	1348	2555	1154
1992	468.69	40.59	23.43	1400	1700	625.83	1335	2530	1186
1993	486.50	42.14	24.33	1400	1600	645.90	1328	2516	1224
1994	504.99	43.74	25.25	1400	1600	666.73	1320	2502	1263
1995	524.18	45.40	26.21	1400	1600	688.35	1313	2488	1304
1996	544.10	47.12	27.20	1200	1500	704.09	1294	2452	1334
1997	564.77	48.91	28.24	1200	1500	720.43	1276	2417	1365
1998	586.24	50.77	29.31	1200	1500	737.39	1258	2384	1397
1999	608.51	52.70	30.43	1200	1500	755.00	1241	2351	1431
2000	631.64	54.71	31.58	1200	1400	776.43	1229	2329	1471
2001	655.64	56.78	32.78	1200	1400	798.67	1218	2308	1513
2002	680.55	58.94	34.03	1200	1400	821.77	1207	2288	1557
2003	706.41	61.18	35.32	1200	1400	845.74	1197	2269	1603
2004	733.26	63.51	36.66	1100	1400	864.26	1179	2234	1638
2005	761.12	65.92	38.06	1100	1400	883.50	1161	2200	1674

Table A-11

PG&E Conservation Power Plant Study
CAC Analysis - Zone 4
Base Case Scenario

Year	Total units (1000)	New units (1000)	Retire units (1000)	New UEC (kWh)	Retire UEC (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	318.00	30.50	15.90	450	540	166.00	522	989	315
1986	333.26	31.93	16.66	450	540	171.37	514	974	325
1987	349.26	33.46	17.46	450	540	177.00	507	960	335
1988	366.03	35.07	18.30	450	540	182.89	500	947	347
1989	383.59	36.75	19.18	450	540	189.07	493	934	358
1990	402.01	38.51	20.10	450	540	195.55	486	922	371
1991	421.30	40.36	21.07	450	540	202.34	480	910	383
1992	441.53	42.30	22.08	450	540	209.45	474	899	397
1993	462.72	44.33	23.14	450	540	216.90	469	888	411
1994	484.93	46.46	24.25	450	540	224.72	463	878	426
1995	508.21	48.69	25.41	450	540	232.91	458	868	441
1996	532.60	51.02	26.63	400	450	241.33	453	859	457
1997	558.16	53.47	27.91	400	450	250.16	448	849	474
1998	584.96	56.04	29.25	400	450	259.42	443	840	492
1999	613.03	58.73	30.65	400	450	269.11	439	832	510
2000	642.46	61.55	32.12	400	450	279.28	435	824	529
2001	673.30	64.50	33.66	400	450	289.93	431	816	549
2002	705.62	67.60	35.28	400	450	301.09	427	809	571
2003	739.49	70.84	36.97	400	450	312.79	423	802	593
2004	774.98	74.24	38.75	400	450	325.05	419	795	616
2005	812.18	77.81	40.61	400	450	337.90	416	788	640

Table A-12

PG&E Conservation Power Plant Study
CAC Analysis - Zone 5
Base Case Scenario

Year	Total units (1000)	New units (1000)	Retire units (1000)	New UEC (kWh)	Retire UEC (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	49.50	4.45	2.48	180	250	10.00	202	383	19
1986	51.58	4.66	2.58	180	250	10.19	198	375	19
1987	53.75	4.85	2.69	180	250	10.40	193	367	20
1988	56.00	5.06	2.80	180	250	10.61	189	359	20
1989	58.35	5.27	2.92	180	250	10.82	186	352	21
1990	60.81	5.49	3.04	180	250	11.05	182	344	21
1991	63.36	5.72	3.17	180	250	11.29	178	338	21
1992	66.02	5.96	3.30	180	250	11.54	175	331	22
1993	68.79	6.21	3.44	180	250	11.80	171	325	22
1994	71.68	6.47	3.58	180	250	12.07	168	319	23
1995	74.69	6.75	3.73	180	180	12.61	169	320	24
1996	77.83	7.03	3.89	140	180	12.89	166	314	24
1997	81.10	7.32	4.05	140	180	13.19	163	308	25
1998	84.51	7.63	4.23	140	180	13.50	160	303	26
1999	88.05	7.95	4.40	140	180	13.82	157	297	26
2000	91.75	8.29	4.59	140	180	14.15	154	292	27
2001	95.61	8.63	4.78	140	180	14.50	152	287	27
2002	99.62	9.00	4.98	140	180	14.86	149	283	28
2003	103.81	9.37	5.19	130	180	15.15	146	276	29
2004	108.17	9.77	5.41	130	180	15.44	143	271	29
2005	112.71	10.18	5.64	130	180	15.75	140	265	30

Table A-13

PG&E Conservation Power Plant Study
Electric Range Analysis
Base Case Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	New Units (1000)	Retire Units (1000)	New UEC (kWh)	Retire UEC (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	1455	743	2198	162	85	760	750	1595	729	234	512
1986	1501	770	2271	161	88	760	750	1651	727	233	530
1987	1550	798	2348	168	91	760	750	1711	729	234	549
1988	1593	825	2418	164	94	760	750	1765	730	234	566
1989	1632	849	2481	159	96	760	750	1814	731	235	582
1990	1674	875	2549	167	99	760	780	1863	731	235	598
1991	1717	901	2618	171	102	760	780	1914	731	235	614
1992	1766	931	2697	184	105	760	780	1972	731	235	633
1993	1811	960	2771	182	108	760	780	2026	731	235	650
1994	1862	991	2853	193	111	760	780	2086	731	235	669
1995	1914	1021	2935	196	114	760	780	2146	731	235	688
1996	1966	1054	3020	202	117	760	780	2208	731	235	708
1997	2023	1087	3110	211	121	760	780	2274	731	235	730
1998	2080	1121	3201	215	124	760	780	2341	731	235	751
1999	2135	1155	3290	217	128	760	780	2406	731	235	772
2000	2195	1190	3385	227	132	760	780	2476	731	235	794
2001	2252	1228	3480	230	135	760	780	2545	731	235	816
2002	2317	1263	3580	239	139	760	780	2618	731	235	840
2003	2380	1298	3678	241	143	720	780	2680	729	234	860
2004	2446	1332	3778	247	147	680	780	2734	724	232	877
2005	2510	1367	3877	250	151	650	780	2778	717	230	891

Table A-14

PG&E Conservation Power Plant Study
Electric Clothes Dryer Analysis
Base Case Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	1439	289	1728	120	67	808	932	1503	870	155	267
1986	1478	302	1780	119	69	808	932	1535	862	153	273
1987	1514	314	1828	117	71	808	932	1564	855	152	278
1988	1549	325	1874	117	73	808	932	1590	849	151	282
1989	1581	335	1916	115	75	808	932	1614	842	150	287
1990	1611	346	1957	116	76	808	932	1636	836	148	291
1991	1646	358	2004	123	78	808	932	1663	830	147	295
1992	1686	370	2056	130	80	808	932	1693	824	146	301
1993	1721	382	2103	127	82	808	932	1720	818	145	305
1994	1762	397	2159	138	84	808	932	1753	812	144	311
1995	1801	408	2209	134	86	800	925	1781	806	143	316
1996	1846	422	2268	145	88	790	915	1814	800	142	322
1997	1889	436	2325	145	90	780	905	1846	794	141	328
1998	1932	451	2383	148	93	770	895	1877	788	140	333
1999	1978	468	2446	156	95	760	885	1911	781	139	339
2000	2022	481	2503	152	97	750	875	1940	775	138	345
2001	2067	496	2563	157	100	740	865	1970	769	137	350
2002	2116	510	2626	163	102	730	855	2002	762	135	356
2003	2168	525	2693	169	105	720	845	2035	756	134	361
2004	2217	539	2756	168	107	710	835	2065	749	133	367
2005	2266	553	2819	170	110	700	825	2093	743	132	372

APPENDIX B

WORKSHEETS FOR THE CURRENT TECHNOLOGY SCENARIO

Table B-1

PG&E Conservation Power Plant Study
Standard Refrigerator Analysis
Current Technology Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	715	712	1427	63	53	550	830	1134	795	106	151
1986	717	721	1438	64	53	550	830	1125	783	104	150
1987	719	729	1448	63	53	500	830	1113	768	102	148
1988	721	737	1458	63	54	500	810	1101	755	101	147
1989	723	744	1467	63	54	450	810	1085	740	99	145
1990	725	752	1477	64	54	450	805	1070	725	97	143
1991	727	761	1488	65	55	450	800	1056	710	95	141
1992	731	771	1502	69	55	425	780	1042	694	92	139
1993	734	781	1515	68	56	425	780	1027	678	90	137
1994	738	792	1530	71	56	425	770	1014	663	88	135
1995	742	804	1546	72	57	425	760	1002	648	86	133
1996	747	817	1564	75	58	400	760	988	632	84	132
1997	752	830	1582	76	58	400	750	974	616	82	130
1998	756	844	1600	76	59	400	740	961	601	80	128
1999	761	858	1619	78	60	400	730	949	586	78	126
2000	766	872	1638	79	60	400	725	937	572	76	125
2001	770	884	1654	76	61	400	715	924	558	74	123
2002	776	894	1670	77	62	400	710	911	545	73	121
2003	781	904	1685	77	62	400	700	898	533	71	120
2004	787	914	1701	78	63	400	695	885	521	69	118
2005	792	924	1716	78	63	400	690	873	509	68	116

Table B-2

PG&E Conservation Power Plant Study
Frost-Free Refrigerator Analysis
Current Technology Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	2089	678	2767	165	102	1127	1345	3567	1289	172	475
1986	2136	698	2834	169	104	1120	1345	3615	1276	170	482
1987	2183	719	2902	172	107	900	1345	3627	1250	166	483
1988	2228	739	2967	172	109	900	1300	3639	1227	163	485
1989	2268	757	3025	167	111	750	1300	3620	1197	159	482
1990	2307	776	3083	169	114	750	1300	3599	1168	156	480
1991	2351	795	3146	177	116	750	1300	3581	1138	152	477
1992	2399	817	3216	186	118	650	1260	3553	1105	147	473
1993	2448	839	3287	189	121	650	1250	3525	1072	143	470
1994	2496	861	3357	191	124	650	1250	3494	1041	139	465
1995	2550	883	3433	200	126	650	1240	3467	1010	135	462
1996	2604	908	3512	205	129	600	1240	3430	977	130	457
1997	2662	932	3594	211	132	600	1230	3394	944	126	452
1998	2717	957	3674	212	135	600	1225	3356	913	122	447
1999	2773	982	3755	216	138	600	1215	3317	883	118	442
2000	2833	1008	3841	224	142	600	1210	3281	854	114	437
2001	2890	1035	3925	226	145	600	1205	3242	826	110	432
2002	2952	1061	4013	233	148	600	1190	3205	799	106	427
2003	3014	1085	4099	234	151	600	1180	3167	773	103	422
2004	3080	1111	4191	243	154	600	1170	3133	747	100	417
2005	3143	1136	4279	242	158	600	1165	3094	723	96	412

Table B-3

PG&E Conservation Power Plant Study
Standard Freezer Analysis
Current Technology Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	691	158	849	45	28	750	910	688	810	107	91
1986	705	162	867	46	29	720	905	695	801	106	92
1987	719	166	885	47	29	650	905	699	789	104	92
1988	732	170	902	46	30	650	900	702	778	102	92
1989	744	174	918	46	31	550	900	700	762	100	92
1990	756	177	933	46	31	550	895	697	747	98	92
1991	768	181	949	47	32	500	880	693	730	96	91
1992	783	186	969	52	32	450	875	688	710	93	91
1993	797	190	987	50	33	450	870	682	691	91	90
1994	812	194	1006	52	34	450	865	676	672	89	89
1995	828	199	1027	55	34	450	860	671	653	86	88
1996	845	205	1050	57	35	400	855	664	632	83	87
1997	862	210	1072	57	36	400	850	656	612	81	86
1998	879	216	1095	59	36	400	845	649	593	78	86
1999	896	221	1117	58	37	400	840	641	574	76	84
2000	913	227	1140	60	38	400	835	634	556	73	83
2001	930	232	1162	60	39	400	830	625	538	71	82
2002	949	237	1186	63	40	400	825	618	521	69	81
2003	968	242	1210	64	40	400	820	610	504	66	80
2004	988	246	1234	64	41	400	810	603	488	64	79
2005	1007	251	1258	65	42	400	800	595	473	62	78

Table B-4

PG&E Conservation Power Plant Study
Frost-Free Freezer Analysis
Current Technology Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	270	56	326	18	11	1137	1900	582	1785	235	77
1986	276	58	334	19	11	1137	1890	582	1743	230	77
1987	281	59	340	17	11	1050	1880	579	1703	224	76
1988	286	61	347	18	12	1050	1870	577	1662	219	76
1989	291	62	353	18	12	950	1860	571	1619	213	75
1990	295	63	358	17	12	950	1850	565	1579	208	74
1991	300	65	365	19	12	950	1840	561	1537	202	74
1992	306	66	372	19	12	820	1830	554	1489	196	73
1993	312	68	380	20	13	820	1820	548	1441	190	72
1994	317	69	386	19	13	820	1810	540	1398	184	71
1995	324	71	395	22	13	820	1800	534	1351	178	70
1996	330	73	403	21	13	750	1780	526	1305	172	69
1997	337	75	412	22	14	750	1760	518	1258	166	68
1998	343	77	420	22	14	750	1740	510	1215	160	67
1999	350	79	429	23	14	750	1720	503	1173	154	66
2000	357	81	438	23	15	750	1700	496	1132	149	65
2001	364	82	446	23	15	750	1680	488	1093	144	64
2002	371	84	455	24	15	750	1660	480	1056	139	63
2003	378	86	464	24	15	750	1640	473	1020	134	62
2004	386	87	473	24	16	750	1620	466	985	130	61
2005	393	89	482	25	16	750	1600	459	952	125	60

Table B-5

PG&E Conservation Power Plant Study
Electric Water Heater Analysis
Single Family Housing
Current Technology Scenario

Year	SF Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	300	32	18	4030	4400	1320	4400	544	163
1986	315	33	18	3290	4400	1349	4282	529	167
1987	329	33	19	1790	4400	1324	4024	497	164
1988	344	35	20	1790	4300	1300	3780	467	161
1989	357	34	21	1790	4300	1271	3561	440	157
1990	370	35	22	1790	4300	1241	3353	414	153
1991	384	36	22	1640	4200	1206	3141	388	149
1992	399	38	23	1640	4200	1171	2935	363	145
1993	415	40	24	1640	4200	1135	2736	338	140
1994	430	40	25	1640	4100	1098	2554	316	136
1995	447	43	26	1490	3500	1071	2396	296	132
1996	464	44	27	1490	3000	1056	2275	281	131
1997	485	49	28	1490	2500	1058	2182	270	131
1998	503	47	29	1490	2000	1070	2128	263	132
1999	522	49	30	1490	1790	1089	2087	258	135
2000	538	47	31	1490	1790	1104	2052	254	136
2001	558	53	33	1490	1790	1124	2014	249	139
2002	578	54	34	1490	1790	1144	1978	245	141
2003	600	57	35	1490	1640	1171	1952	241	145
2004	621	57	36	1490	1640	1197	1927	238	148
2005	643	60	38	1490	1640	1224	1904	235	151

Table B-6

PG&E Conservation Power Plant Study
Electric Water Heater Analysis
Multi-Family and Mobile Housing
Current Technology Scenario

Year	SF Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	105	32	6	2500	3000	294	2800	346	36
1986	112	14	7	2420	3000	307	2742	339	38
1987	118	13	7	2420	3000	318	2692	333	39
1988	124	13	7	2420	3000	328	2645	327	41
1989	129	13	8	2420	3000	336	2603	322	42
1990	134	13	8	2020	3000	338	2524	312	42
1991	140	14	8	2020	2900	343	2451	303	42
1992	146	15	9	2020	2800	349	2388	295	43
1993	152	15	9	2020	2800	354	2328	288	44
1994	160	17	9	2020	2700	364	2273	281	45
1995	167	17	10	1540	2650	364	2177	269	45
1996	175	18	10	1540	2600	365	2086	258	45
1997	183	19	11	1540	2500	367	2006	248	45
1998	191	19	11	1540	2420	370	1935	239	46
1999	200	21	12	1540	2420	373	1866	231	46
2000	208	20	12	1540	2420	375	1802	223	46
2001	216	21	13	1540	2420	376	1741	215	47
2002	221	18	13	1540	2020	378	1709	211	47
2003	229	21	13	1540	2020	384	1675	207	47
2004	236	21	14	1540	2020	388	1643	203	48
2005	243	21	14	1540	2020	392	1612	199	48

Table B-7

PG&E Conservation Power Plant Study
Lighting Analysis
Current Technology Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	UEC Stock (kWh)	Total Usage (GWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	2288	1309	3597	1000	3597	64	230
1986	2335	1342	3677	1000	3677	64	235
1987	2381	1375	3756	944	3546	60	227
1988	2424	1406	3830	944	3616	60	232
1989	2462	1434	3896	858	3343	55	214
1990	2502	1464	3966	858	3403	55	218
1991	2544	1494	4038	858	3465	55	222
1992	2593	1529	4122	757	3120	48	200
1993	2640	1564	4204	757	3182	48	204
1994	2690	1600	4290	757	3248	48	208
1995	2742	1638	4380	757	3316	48	212
1996	2797	1678	4475	610	2730	39	175
1997	2853	1719	4572	610	2789	39	179
1998	2909	1761	4670	610	2849	39	182
1999	2966	1802	4768	610	2908	39	186
2000	3023	1845	4868	610	2969	39	190
2001	3081	1888	4969	610	3031	39	194
2002	3143	1927	5070	610	3093	39	198
2003	3207	1965	5172	610	3155	39	202
2004	3270	2004	5274	610	3217	39	206
2005	3333	2043	5376	610	3279	39	210

Table B-8

PG&E Conservation Power Plant Study
CAC Analysis - Zone 1
Current Technology Scenario

Year	Total units (1000)	New units (1000)	Retire units (1000)	Base New UEC (kWh)	New UEC factor	CT New UEC (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	41.80	5.35	2.09	840	1.000	840	900	32.50	778	1473	62
1986	45.40	5.87	2.27	840	0.767	644	900	34.24	754	1429	65
1987	49.00	6.05	2.45	840	0.767	644	900	35.93	733	1390	68
1988	52.60	6.23	2.63	840	0.688	578	900	37.17	707	1339	70
1989	56.20	6.41	2.81	840	0.688	578	900	38.34	682	1293	73
1990	59.80	6.59	2.99	840	0.688	578	900	39.46	660	1250	75
1991	63.40	6.77	3.17	840	0.688	578	900	40.52	639	1211	77
1992	67.00	6.95	3.35	840	0.624	524	900	41.15	614	1164	78
1993	70.60	7.13	3.53	840	0.624	524	900	41.71	591	1119	79
1994	74.20	7.31	3.71	840	0.624	524	850	42.38	571	1082	80
1995	77.80	7.49	3.89	840	0.624	524	850	43.00	553	1047	81
1996	81.40	7.67	4.07	750	0.624	468	850	43.13	530	1004	82
1997	85.00	7.85	4.25	750	0.608	456	800	43.31	510	966	82
1998	88.60	8.03	4.43	750	0.608	456	800	43.43	490	929	82
1999	92.20	8.21	4.61	750	0.608	456	700	43.95	477	903	83
2000	95.80	8.39	4.79	700	0.608	426	700	44.17	461	874	84
2001	99.40	8.57	4.97	700	0.608	426	650	44.58	449	850	84
2002	103.00	8.75	5.15	700	0.608	426	600	45.22	439	832	86
2003	106.60	8.93	5.33	650	0.608	395	600	45.55	427	810	86
2004	110.20	9.11	5.51	650	0.608	395	550	46.12	418	793	87
2005	113.80	9.29	5.69	650	0.608	395	550	46.66	410	777	88

Table B-9

PG&E Conservation Power Plant Study
CAC Analysis - Zone 2
Current Technology Scenario

Year	Total units (1000)	New units (1000)	Retire units (1000)	Base New UEC (kWh)	New UEC factor	CT New UEC (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	162.40	17.00	8.12	950	1.000	950	1000	147.00	905	1715	279
1986	171.40	17.57	8.57	950	0.739	702	1000	150.77	880	1667	286
1987	180.40	18.02	9.02	950	0.739	702	1000	154.40	856	1622	293
1988	189.40	18.47	9.47	950	0.640	608	1000	156.16	824	1562	296
1989	198.40	18.92	9.92	950	0.640	608	1000	157.74	795	1507	299
1990	207.40	19.37	10.37	950	0.640	608	1000	159.15	767	1454	302
1991	216.40	19.82	10.82	950	0.640	608	1000	160.38	741	1404	304
1992	225.40	20.27	11.27	950	0.539	512	1000	159.49	708	1341	302
1993	234.40	20.72	11.72	950	0.539	512	950	158.96	678	1285	301
1994	243.40	21.17	12.17	950	0.539	512	950	158.24	650	1232	300
1995	252.40	21.62	12.62	950	0.539	512	900	157.95	626	1186	299
1996	263.40	24.17	13.17	750	0.539	404	900	155.87	592	1121	295
1997	274.40	24.72	13.72	750	0.485	364	850	153.20	558	1058	290
1998	285.40	25.27	14.27	750	0.485	364	800	150.98	529	1002	286
1999	296.40	25.82	14.82	750	0.485	364	800	148.51	501	949	281
2000	307.40	26.37	15.37	700	0.485	340	750	145.94	475	900	277
2001	318.40	26.92	15.92	700	0.485	340	750	143.15	450	852	271
2002	329.40	27.47	16.47	700	0.485	340	700	140.95	428	811	267
2003	340.40	28.02	17.02	650	0.485	315	700	137.87	405	767	261
2004	353.00	30.25	17.65	650	0.485	315	600	136.81	388	734	259
2005	365.00	30.25	18.25	650	0.485	315	600	135.38	371	703	257

Table B-10

PG&E Conservation Power Plant Study
CAC Analysis - Zone 3
Current Technology Scenario

Year	Total units (1000)	New units (1000)	Retire units (1000)	Base New UEC (kWh)	New UEC factor	CT New UEC (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	361.00	31.20	18.05	1400	1.000	1400	1800	523.00	1449	2745	991
1986	374.72	32.45	18.74	1400	0.739	1035	1800	522.85	1395	2644	991
1987	388.96	33.69	19.45	1400	0.739	1035	1800	522.70	1344	2547	991
1988	403.74	34.97	20.19	1400	0.640	896	1700	519.71	1287	2439	985
1989	419.08	36.30	20.95	1400	0.640	896	1700	516.61	1233	2336	979
1990	435.00	37.68	21.75	1400	0.640	896	1700	513.39	1180	2236	973
1991	451.53	39.11	22.58	1400	0.640	896	1700	510.05	1130	2141	967
1992	468.69	40.59	23.43	1400	0.539	755	1700	500.84	1069	2025	949
1993	486.50	42.14	24.33	1400	0.539	755	1600	493.72	1015	1923	936
1994	504.99	43.74	25.25	1400	0.539	755	1600	486.32	963	1825	922
1995	524.18	45.40	26.21	1400	0.539	755	1500	481.27	918	1740	912
1996	544.10	47.12	27.20	1200	0.539	647	1400	473.66	871	1650	898
1997	564.77	48.91	28.24	1200	0.485	582	1300	465.42	824	1562	882
1998	586.24	50.77	29.31	1200	0.485	582	1200	459.80	784	1486	871
1999	608.51	52.70	30.43	1200	0.485	582	1100	457.00	751	1423	866
2000	631.64	54.71	31.58	1200	0.485	582	1050	455.68	721	1367	863
2001	655.64	56.78	32.78	1200	0.485	582	1050	454.30	693	1313	861
2002	680.55	58.94	34.03	1200	0.485	582	1050	452.88	665	1261	858
2003	706.41	61.18	35.32	1200	0.485	582	900	456.70	647	1225	865
2004	733.26	63.51	36.66	1100	0.485	534	900	457.58	624	1183	867
2005	761.12	65.92	38.06	1100	0.485	534	900	458.50	602	1142	869

Table B-11

PG&E Conservation Power Plant Study
CAC Analysis - Zone 4
Current Technology Scenario

Year	Total units (1000)	New units (1000)	Retire units (1000)	Base New UEC (kWh)	New UEC factor	CT New UEC (kWh)	Retire UEC (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	318.00	30.50	15.90	450	1.000	450	540	166.00	522	989	315
1986	333.26	31.93	16.66	450	0.767	345	540	168.02	504	955	318
1987	349.26	33.46	17.46	450	0.767	345	540	170.14	487	923	322
1988	366.03	35.07	18.30	450	0.688	310	540	171.11	467	886	324
1989	383.59	36.75	19.18	450	0.688	310	540	172.13	449	850	326
1990	402.01	38.51	20.10	450	0.688	310	540	173.20	431	816	328
1991	421.30	40.36	21.07	450	0.688	310	540	174.32	414	784	330
1992	441.53	42.30	22.08	450	0.624	281	540	174.28	395	748	330
1993	462.72	44.33	23.14	450	0.624	281	540	174.23	377	714	330
1994	484.93	46.46	24.25	450	0.624	281	540	174.19	359	681	330
1995	508.21	48.69	25.41	450	0.624	281	540	174.14	343	649	330
1996	532.60	51.02	26.63	400	0.624	250	450	174.89	328	622	331
1997	558.16	53.47	27.91	400	0.608	243	450	175.33	314	595	332
1998	584.96	56.04	29.25	400	0.608	243	450	175.80	301	570	333
1999	613.03	58.73	30.65	400	0.608	243	450	176.29	288	545	334
2000	642.46	61.55	32.12	400	0.608	243	450	176.81	275	521	335
2001	673.30	64.50	33.66	400	0.608	243	350	180.71	268	509	342
2002	705.62	67.60	35.28	400	0.608	243	350	184.80	262	496	350
2003	739.49	70.84	36.97	400	0.608	243	300	190.94	258	489	362
2004	774.98	74.24	38.75	400	0.608	243	300	197.37	255	483	374
2005	812.18	77.81	40.61	400	0.608	243	300	204.11	251	476	387

Table B-12

PG&E Conservation Power Plant Study
CAC Analysis - Zone 5
Current Technology Scenario

Year	Total units (1000)	New units (1000)	Retire units (1000)	Base New UEC (kWh)	New UEC factor	CT New UEC (kWh)	Retire UEC (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	49.50	4.45	2.48	180	1.000	180	250	10.00	202	383	19
1986	51.58	4.66	2.58	180	0.767	138	250	10.00	194	367	19
1987	53.75	4.85	2.69	180	0.767	138	250	10.00	186	352	19
1988	56.00	5.06	2.80	180	0.688	124	250	9.92	177	336	19
1989	58.35	5.27	2.92	180	0.688	124	250	9.85	169	320	19
1990	60.81	5.49	3.04	180	0.688	124	250	9.77	161	304	19
1991	63.36	5.72	3.17	180	0.688	124	250	9.68	153	290	18
1992	66.02	5.96	3.30	180	0.624	112	250	9.53	144	273	18
1993	68.79	6.21	3.44	180	0.624	112	220	9.47	138	261	18
1994	71.68	6.47	3.58	180	0.624	112	200	9.48	132	251	18
1995	74.69	6.75	3.73	180	0.624	112	190	9.53	128	242	18
1996	77.83	7.03	3.89	140	0.624	87	180	9.44	121	230	18
1997	81.10	7.32	4.05	140	0.608	85	175	9.35	115	219	18
1998	84.51	7.63	4.23	140	0.608	85	170	9.29	110	208	18
1999	88.05	7.95	4.40	140	0.608	85	160	9.26	105	199	18
2000	91.75	8.29	4.59	140	0.608	85	150	9.27	101	192	18
2001	95.61	8.63	4.78	140	0.608	85	140	9.34	98	185	18
2002	99.62	9.00	4.98	140	0.608	85	140	9.41	94	179	18
2003	103.81	9.37	5.19	130	0.608	79	130	9.47	91	173	18
2004	108.17	9.77	5.41	130	0.608	79	120	9.60	89	168	18
2005	112.71	10.18	5.64	130	0.608	79	120	9.73	86	164	18

Table B-13

PG&E Conservation Power Plant Study
Electric Range Analysis
Current Technology Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	New Units (1000)	Retire Units (1000)	New UEC (kWh)	Retire UEC (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	1455	743	2198	162	85	760	750	1595	729	234	512
1986	1501	770	2271	161	88	760	750	1651	727	233	530
1987	1550	798	2348	168	91	760	750	1711	729	234	549
1988	1593	825	2418	164	94	760	750	1765	730	234	566
1989	1632	849	2481	159	96	760	750	1814	731	235	582
1990	1674	875	2549	167	99	760	780	1863	731	235	598
1991	1717	901	2618	171	102	760	780	1914	731	235	614
1992	1766	931	2697	184	105	760	780	1972	731	235	633
1993	1811	960	2771	182	108	760	780	2026	731	235	650
1994	1862	991	2853	193	111	760	780	2086	731	235	669
1995	1914	1021	2935	196	114	760	780	2146	731	235	688
1996	1966	1054	3020	202	117	760	780	2208	731	235	708
1997	2023	1087	3110	211	121	760	780	2274	731	235	730
1998	2080	1121	3201	215	124	760	780	2341	731	235	751
1999	2135	1155	3290	217	128	760	780	2406	731	235	772
2000	2195	1190	3385	227	132	760	780	2476	731	235	794
2001	2252	1228	3480	230	135	760	780	2545	731	235	816
2002	2317	1263	3580	239	139	760	780	2618	731	235	840
2003	2380	1298	3678	241	143	720	780	2680	729	234	860
2004	2446	1332	3778	247	147	680	780	2734	724	232	877
2005	2510	1367	3877	250	151	650	780	2778	717	230	891

Table B-14

PG&E Conservation Power Plant Study
Electric Clothes Dryer Analysis
Current Technology Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	1439	289	1728	120	67	808	932	1503	870	155	267
1986	1478	302	1780	119	69	808	932	1535	862	153	273
1987	1514	314	1828	117	71	808	932	1564	855	152	278
1988	1549	325	1874	117	73	808	932	1590	849	151	282
1989	1581	335	1916	115	75	808	932	1614	842	150	287
1990	1611	346	1957	116	76	808	932	1636	836	148	291
1991	1646	358	2004	123	78	808	932	1663	830	147	295
1992	1686	370	2056	130	80	808	932	1693	824	146	301
1993	1721	382	2103	127	82	808	932	1720	818	145	305
1994	1762	397	2159	138	84	808	932	1753	812	144	311
1995	1801	408	2209	134	86	800	925	1781	806	143	316
1996	1846	422	2268	145	88	790	915	1814	800	142	322
1997	1889	436	2325	145	90	780	905	1846	794	141	328
1998	1932	451	2383	148	93	770	895	1877	788	140	333
1999	1978	468	2446	156	95	760	885	1911	781	139	339
2000	2022	481	2503	152	97	750	875	1940	775	138	345
2001	2067	496	2563	157	100	740	865	1970	769	137	350
2002	2116	510	2626	163	102	730	855	2002	762	135	356
2003	2168	525	2693	169	105	720	845	2035	756	134	361
2004	2217	539	2756	168	107	710	835	2065	749	133	367
2005	2266	553	2819	170	110	700	825	2093	743	132	372

Table C-2

PG&E Conservation Power Plant Study
Frost-Free Refrigerator Analysis
Technical Potential Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	2089	678	2767	165	102	1127	1345	3567	1289	172	475
1986	2136	698	2834	169	104	900	1345	3578	1263	168	477
1987	2183	719	2902	172	107	900	1345	3590	1237	165	478
1988	2228	739	2967	172	109	900	1300	3602	1214	162	480
1989	2268	757	3025	167	111	675	1300	3570	1180	157	476
1990	2307	776	3083	169	114	675	1300	3537	1147	153	471
1991	2351	795	3146	177	116	675	1300	3506	1114	148	467
1992	2399	817	3216	186	118	530	1260	3455	1074	143	460
1993	2448	839	3287	189	121	530	1250	3404	1036	138	453
1994	2496	861	3357	191	124	530	1250	3351	998	133	446
1995	2550	883	3433	200	126	530	1240	3300	961	128	440
1996	2604	908	3512	205	129	420	1240	3225	918	122	430
1997	2662	932	3594	211	132	420	1230	3151	877	117	420
1998	2717	957	3674	212	135	420	1225	3075	837	111	410
1999	2773	982	3755	216	138	420	1215	2997	798	106	399
2000	2833	1008	3841	224	142	420	1210	2920	760	101	389
2001	2890	1035	3925	226	145	280	1205	2809	716	95	374
2002	2952	1061	4013	233	148	280	1190	2699	672	90	360
2003	3014	1085	4099	234	151	280	1160	2589	632	84	345
2004	3080	1111	4191	243	154	280	1130	2482	592	79	331
2005	3143	1136	4279	242	158	280	1100	2377	555	74	317

Table C-3

PG&E Conservation Power Plant Study
Standard Freezer Analysis
Technical Potential Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	691	158	849	45	28	750	910	688	810	107	91
1986	705	162	867	46	29	720	905	695	801	106	92
1987	719	166	885	47	29	650	905	699	789	104	92
1988	732	170	902	46	30	650	900	702	778	102	92
1989	744	174	918	46	31	425	900	694	756	100	91
1990	756	177	933	46	31	425	895	685	735	97	90
1991	768	181	949	47	32	425	880	678	714	94	89
1992	783	186	969	52	32	272	875	663	685	90	87
1993	797	190	987	50	33	272	870	648	657	87	85
1994	812	194	1006	52	34	272	865	634	630	83	83
1995	828	199	1027	55	34	272	860	619	603	79	82
1996	845	205	1050	57	35	190	855	600	571	75	79
1997	862	210	1072	57	36	190	850	580	541	71	76
1998	879	216	1095	59	36	190	845	561	512	67	74
1999	896	221	1117	58	37	190	840	540	484	64	71
2000	913	227	1140	60	38	190	835	520	456	60	69
2001	930	232	1162	60	39	190	830	499	430	57	66
2002	949	237	1186	63	40	190	825	479	404	53	63
2003	968	242	1210	64	40	190	820	458	378	50	60
2004	988	246	1234	64	41	190	810	437	354	47	58
2005	1007	251	1258	65	42	190	800	415	330	44	55

Table C-6

PG&E Conservation Power Plant Study
Electric Water Heater Analysis
Multi-Family and Mobile Housing
Technical Potential Scenario

Year	SF Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	105	32	6	2500	3000	294	2800	346	36
1986	112	14	7	2270	3000	305	2724	337	38
1987	118	13	7	2270	3000	314	2659	329	39
1988	124	13	7	2270	3000	322	2597	321	40
1989	129	13	8	2270	3000	328	2542	314	41
1990	134	13	8	1810	3000	328	2445	302	41
1991	140	14	8	1810	2900	330	2354	291	41
1992	146	15	9	1810	2800	332	2274	281	41
1993	152	15	9	1810	2700	335	2204	272	41
1994	160	17	9	1810	2600	342	2138	264	42
1995	167	17	10	1290	2500	339	2032	251	42
1996	175	18	10	1290	2400	338	1933	239	42
1997	183	19	11	1290	2300	338	1846	228	42
1998	191	19	11	1290	2270	337	1766	218	42
1999	200	21	12	1290	2270	337	1687	209	42
2000	208	20	12	1290	2270	336	1615	200	42
2001	216	21	13	1290	2270	334	1546	191	41
2002	221	18	13	1290	1810	334	1510	187	41
2003	229	21	13	1290	1810	337	1472	182	42
2004	236	21	14	1290	1810	339	1436	178	42
2005	243	21	14	1290	1810	341	1401	173	42

Table C-7

PG&E Conservation Power Plant Study
Lighting Analysis
Technical Potential Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	UEC Stock (kWh)	Total Usage (GWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	2288	1309	3597	1000	3597	64	230
1986	2335	1342	3677	1000	3677	64	235
1987	2381	1375	3756	944	3546	60	227
1988	2424	1406	3830	944	3616	60	232
1989	2462	1434	3896	837	3261	54	209
1990	2502	1464	3966	837	3320	54	213
1991	2544	1494	4038	837	3380	54	216
1992	2593	1529	4122	712	2935	46	188
1993	2640	1564	4204	712	2993	46	192
1994	2690	1600	4290	712	3054	46	196
1995	2742	1638	4380	712	3119	46	200
1996	2797	1678	4475	520	2327	33	149
1997	2853	1719	4572	520	2377	33	152
1998	2909	1761	4670	520	2428	33	156
1999	2966	1802	4768	520	2479	33	159
2000	3023	1845	4868	520	2531	33	162
2001	3081	1888	4969	520	2584	33	165
2002	3143	1927	5070	520	2636	33	169
2003	3207	1965	5172	520	2689	33	172
2004	3270	2004	5274	520	2742	33	176
2005	3333	2043	5376	520	2796	33	179

Table C-8

PG&E Conservation Power Plant Study
CAC Analysis - Zone 1
Technical Potential Scenario

Year	Total units (1000)	New units (1000)	Retire units (1000)	Base New UEC (kWh)	New UEC factor	TP New UEC (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	41.80	5.35	2.09	840	1.000	840	900	32.50	778	1473	62
1986	45.40	5.87	2.27	840	0.767	644	900	34.24	754	1429	65
1987	49.00	6.05	2.45	840	0.767	644	900	35.93	733	1390	68
1988	52.60	6.23	2.63	840	0.624	524	900	36.83	700	1327	70
1989	56.20	6.41	2.81	840	0.624	524	900	37.66	670	1270	71
1990	59.80	6.59	2.99	840	0.624	524	900	38.42	643	1218	73
1991	63.40	6.77	3.17	840	0.624	524	900	39.12	617	1169	74
1992	67.00	6.95	3.35	840	0.559	470	900	39.37	588	1113	75
1993	70.60	7.13	3.53	840	0.559	470	900	39.54	560	1061	75
1994	74.20	7.31	3.71	840	0.559	470	850	39.82	537	1017	75
1995	77.80	7.49	3.89	840	0.559	470	850	40.03	515	975	76
1996	81.40	7.67	4.07	750	0.559	419	850	39.79	489	926	75
1997	85.00	7.85	4.25	750	0.486	364	800	39.25	462	875	74
1998	88.60	8.03	4.43	750	0.486	364	800	38.63	436	826	73
1999	92.20	8.21	4.61	750	0.486	364	700	38.39	416	789	73
2000	95.80	8.39	4.79	700	0.486	340	700	37.90	396	750	72
2001	99.40	8.57	4.97	700	0.486	340	600	37.83	381	721	72
2002	103.00	8.75	5.15	700	0.486	340	550	37.97	369	699	72
2003	106.60	8.93	5.33	650	0.486	316	550	37.86	355	673	72
2004	110.20	9.11	5.51	650	0.486	316	500	37.99	345	653	72
2005	113.80	9.29	5.69	650	0.486	316	500	38.08	335	634	72

Table C-9

PG&E Conservation Power Plant Study
CAC Analysis - Zone 2
Technical Potential Scenario

Year	Total units (1000)	New units (1000)	Retire units (1000)	Base New UEC (kWh)	New UEC factor	TP New UEC (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	162.40	17.00	8.12	950	1.000	950	1000	147.00	905	1715	279
1986	171.40	17.57	8.57	950	0.710	674	1000	150.28	877	1661	285
1987	180.40	18.02	9.02	950	0.710	674	1000	153.42	850	1612	291
1988	189.40	18.47	9.47	950	0.404	384	1000	151.03	797	1511	286
1989	198.40	18.92	9.92	950	0.404	384	1000	148.38	748	1417	281
1990	207.40	19.37	10.37	950	0.404	384	1000	145.44	701	1329	276
1991	216.40	19.82	10.82	950	0.404	384	1000	142.23	657	1245	270
1992	225.40	20.27	11.27	950	0.208	198	1000	134.96	599	1135	256
1993	234.40	20.72	11.72	950	0.208	198	950	127.92	546	1034	242
1994	243.40	21.17	12.17	950	0.208	198	950	120.54	495	938	228
1995	252.40	21.62	12.62	950	0.208	198	900	113.46	450	852	215
1996	263.40	24.17	13.17	750	0.208	156	900	105.38	400	758	200
1997	274.40	24.72	13.72	750	0.157	118	850	96.62	352	667	183
1998	285.40	25.27	14.27	750	0.157	118	800	88.18	309	586	167
1999	296.40	25.82	14.82	750	0.157	118	800	79.37	268	507	150
2000	307.40	26.37	15.37	700	0.157	110	700	71.51	233	441	136
2001	318.40	26.92	15.92	700	0.157	110	700	63.32	199	377	120
2002	329.40	27.47	16.47	700	0.157	110	700	54.81	166	315	104
2003	340.40	28.02	17.02	650	0.157	102	350	51.71	152	288	98
2004	353.00	30.25	17.65	650	0.157	102	350	48.62	138	261	92
2005	365.00	30.25	18.25	650	0.157	102	350	45.32	124	235	86

Table C-10

PG&E Conservation Power Plant Study
CAC Analysis - Zone 3
Technical Potential Scenario

Year	Total units (1000)	New units (1000)	Retire units (1000)	Base New UEC (kWh)	New UEC factor	TP New UEC (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	361.00	31.20	18.05	1400	1.000	1400	1800	523.00	1449	2745	991
1986	374.72	32.45	18.74	1400	0.710	994	1800	521.53	1392	2637	988
1987	388.96	33.69	19.45	1400	0.710	994	1800	520.01	1337	2533	985
1988	403.74	34.97	20.19	1400	0.404	566	1700	505.47	1252	2372	958
1989	419.08	36.30	20.95	1400	0.404	566	1700	490.38	1170	2217	929
1990	435.00	37.68	21.75	1400	0.404	566	1700	474.71	1091	2068	900
1991	451.53	39.11	22.58	1400	0.404	566	1700	458.45	1015	1924	869
1992	468.69	40.59	23.43	1400	0.208	291	1700	430.43	918	1740	816
1993	486.50	42.14	24.33	1400	0.208	291	1600	403.78	830	1573	765
1994	504.99	43.74	25.25	1400	0.208	291	1600	376.12	745	1411	713
1995	524.18	45.40	26.21	1400	0.208	291	1500	350.03	668	1265	663
1996	544.10	47.12	27.20	1200	0.208	250	1400	323.70	595	1127	613
1997	564.77	48.91	28.24	1200	0.157	188	1200	299.03	529	1003	567
1998	586.24	50.77	29.31	1200	0.157	188	1100	276.35	471	893	524
1999	608.51	52.70	30.43	1200	0.157	188	1000	255.86	420	797	485
2000	631.64	54.71	31.58	1200	0.157	188	900	237.74	376	713	451
2001	655.64	56.78	32.78	1200	0.157	188	900	218.93	334	633	415
2002	680.55	58.94	34.03	1200	0.157	188	900	199.41	293	555	378
2003	706.41	61.18	35.32	1200	0.157	188	600	189.75	269	509	360
2004	733.26	63.51	36.66	1100	0.157	173	600	178.72	244	462	339
2005	761.12	65.92	38.06	1100	0.157	173	600	167.27	220	416	317

Table C-11

PG&E Conservation Power Plant Study
CAC Analysis - Zone 4
Technical Potential Scenario

Year	Total units (1000)	New units (1000)	Retire units (1000)	Base New UEC (kWh)	New UEC factor	TP New UEC (kWh)	Retire UEC (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	318.00	30.50	15.90	450	1.000	450	540	166.00	522	989	315
1986	333.26	31.93	16.66	450	0.767	345	540	168.02	504	955	318
1987	349.26	33.46	17.46	450	0.767	345	540	170.14	487	923	322
1988	366.03	35.07	18.30	450	0.624	281	540	170.10	465	881	322
1989	383.59	36.75	19.18	450	0.624	281	540	170.07	443	840	322
1990	402.01	38.51	20.10	450	0.624	281	540	170.03	423	801	322
1991	421.30	40.36	21.07	450	0.624	281	540	169.98	403	765	322
1992	441.53	42.30	22.08	450	0.559	252	540	168.70	382	724	320
1993	462.72	44.33	23.14	450	0.559	252	540	167.36	362	685	317
1994	484.93	46.46	24.25	450	0.559	252	540	165.95	342	649	314
1995	508.21	48.69	25.41	450	0.559	252	540	164.48	324	613	312
1996	532.60	51.02	26.63	400	0.559	224	450	163.91	308	583	311
1997	558.16	53.47	27.91	400	0.486	194	450	161.74	290	549	306
1998	584.96	56.04	29.25	400	0.486	194	450	159.47	273	517	302
1999	613.03	58.73	30.65	400	0.486	194	450	157.10	256	486	298
2000	642.46	61.55	32.12	400	0.486	194	450	154.61	241	456	293
2001	673.30	64.50	33.66	400	0.486	194	350	155.36	231	437	294
2002	705.62	67.60	35.28	400	0.486	194	350	156.16	221	419	296
2003	739.49	70.84	36.97	400	0.486	194	300	158.84	215	407	301
2004	774.98	74.24	38.75	400	0.486	194	275	162.61	210	398	308
2005	812.18	77.81	40.61	400	0.486	194	250	167.59	206	391	318

Table C-12

PG&E Conservation Power Plant Study
CAC Analysis - Zone 5
Technical Potential Scenario

Year	Total units (1000)	New units (1000)	Retire units (1000)	Base New UEC (kWh)	New UEC factor	TP New UEC (kWh)	Retire UEC (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	49.50	4.45	2.48	180	1.000	180	250	10.00	202	383	19
1986	51.58	4.66	2.58	180	0.767	138	250	10.00	194	367	19
1987	53.75	4.85	2.69	180	0.767	138	250	10.00	186	352	19
1988	56.00	5.06	2.80	180	0.624	112	250	9.86	176	334	19
1989	58.35	5.27	2.92	180	0.624	112	250	9.73	167	316	18
1990	60.81	5.49	3.04	180	0.624	112	250	9.58	158	299	18
1991	63.36	5.72	3.17	180	0.624	112	250	9.43	149	282	18
1992	66.02	5.96	3.30	180	0.559	101	250	9.21	139	264	17
1993	68.79	6.21	3.44	180	0.559	101	220	9.08	132	250	17
1994	71.68	6.47	3.58	180	0.559	101	200	9.01	126	238	17
1995	74.69	6.75	3.73	180	0.559	101	190	8.98	120	228	17
1996	77.83	7.03	3.89	140	0.559	78	180	8.83	113	215	17
1997	81.10	7.32	4.05	140	0.486	68	175	8.62	106	201	16
1998	84.51	7.63	4.23	140	0.486	68	170	8.42	100	189	16
1999	88.05	7.95	4.40	140	0.486	68	160	8.26	94	178	16
2000	91.75	8.29	4.59	140	0.486	68	150	8.13	89	168	15
2001	95.61	8.63	4.78	140	0.486	68	140	8.05	84	160	15
2002	99.62	9.00	4.98	140	0.486	68	140	7.97	80	152	15
2003	103.81	9.37	5.19	130	0.486	63	110	7.99	77	146	15
2004	108.17	9.77	5.41	130	0.486	63	110	8.01	74	140	15
2005	112.71	10.18	5.64	130	0.486	63	110	8.03	71	135	15

Table C-13

PG&E Conservation Power Plant Study
Electric Range Analysis
Technical Potential Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	New Units (1000)	Retire Units (1000)	New UEC (kWh)	Retire UEC (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	1455	743	2198	162	85	760	750	1595	729	234	512
1986	1501	770	2271	161	88	760	750	1651	727	233	530
1987	1550	798	2348	168	91	684	750	1698	723	232	545
1988	1593	825	2418	164	94	684	750	1740	719	231	558
1989	1632	849	2481	159	96	596	750	1762	710	228	565
1990	1674	875	2549	167	99	596	780	1785	700	225	572
1991	1717	901	2618	171	102	596	780	1807	690	221	580
1992	1766	931	2697	184	105	508	780	1819	674	216	583
1993	1811	960	2771	182	108	508	780	1827	659	211	586
1994	1862	991	2853	193	111	508	780	1838	644	207	590
1995	1914	1021	2935	196	114	508	780	1849	630	202	593
1996	1966	1054	3020	202	117	508	780	1860	616	198	597
1997	2023	1087	3110	211	121	508	780	1873	602	193	601
1998	2080	1121	3201	215	124	508	780	1885	589	189	605
1999	2135	1155	3290	217	128	508	780	1896	576	185	608
2000	2195	1190	3385	227	132	508	780	1908	564	181	612
2001	2252	1228	3480	230	135	508	780	1920	552	177	616
2002	2317	1263	3580	239	139	508	760	1935	541	173	621
2003	2380	1298	3678	241	143	508	760	1949	530	170	625
2004	2446	1332	3778	247	147	508	730	1967	521	167	631
2005	2510	1367	3877	250	151	508	700	1989	513	165	638

Table C-14

PG&E Conservation Power Plant Study
Electric Clothes Dryer Analysis
Technical Potential Scenario

Year	SF Stock (1000)	Other Stock (1000)	Total Stock (1000)	New Units (1000)	Retire Units (1000)	UEC New (kWh)	UEC Retire (kWh)	Total Usage (GWh)	UEC Stock (kWh)	Unit Peak Demand (watts)	Agg Peak Demand (MW)
1985	1439	289	1728	120	67	808	932	1503	870	155	267
1986	1478	302	1780	119	69	808	932	1535	862	153	273
1987	1514	314	1828	117	71	808	932	1564	855	152	278
1988	1549	325	1874	117	73	526	932	1557	831	148	277
1989	1581	335	1916	115	75	526	932	1548	808	144	275
1990	1611	346	1957	116	76	526	932	1538	786	140	273
1991	1646	358	2004	123	78	526	932	1530	764	136	272
1992	1686	370	2056	130	80	425	932	1511	735	131	268
1993	1721	382	2103	127	82	425	932	1489	708	126	264
1994	1762	397	2159	138	84	425	932	1469	680	121	261
1995	1801	408	2209	134	86	425	925	1446	655	116	257
1996	1846	422	2268	145	88	364	915	1418	625	111	252
1997	1889	436	2325	145	90	364	905	1389	598	106	247
1998	1932	451	2383	148	93	364	895	1361	571	101	242
1999	1978	468	2446	156	95	364	885	1333	545	97	237
2000	2022	481	2503	152	97	364	875	1303	521	92	231
2001	2067	496	2563	157	100	364	855	1275	498	88	227
2002	2116	510	2626	163	102	364	835	1249	476	85	222
2003	2168	525	2693	169	105	364	815	1225	455	81	218
2004	2217	539	2756	168	107	364	795	1201	436	77	213
2005	2266	553	2819	170	110	364	775	1178	418	74	209