CALIFORNIA STATEWIDE RESIDENTIAL SECTOR ENERGY EFFICIENCY POTENTIAL STUDY

Study ID #SW063

FINAL REPORT

VOLUME 1 OF 2

Main Report

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EXECUTIVE SUMMARY

California is the nation's most efficient state in terms of per capita electricity consumption. Since 1973, per capita electricity consumption in the United States increased by 50 percent, while, remarkably, per capita use in California held constant. Much of this is likely the direct result of the state's efforts to fund and promote energy efficiency through programs and enactment of more stringent state standards. It is estimated that over the past 25 years these programs and policies have resulted in savings of 9,000 megawatts and 2 billion therms.

Yet, significant energy savings potential remains. For electricity, this study finds that the more than $520 million currently proposed to be spent on programs to promote efficiency in California's residential sector over the next 10 years will yield roughly $1.9 billion in electricity cost savings. Further, the study shows that increasing funds for programs targeting the residential sector alone would not only further reduce consumption, but also net billions of dollars in additional savings. For example, by increasing the amount spent on such programs from $0.5 billion to $1.4 billion, the state could save $3.8 billion on electricity costs.

For natural gas, the study finds that the approximately $230 million currently proposed for residential energy efficiency retrofits over the next 10 years will yield about $317 million in gas cost savings. Increasing spending over the next 10 years to $380 million could save approximately $525 million on natural gas costs.

This is the most comprehensive study of residential energy-efficiency potential conducted in California, the world's fifth biggest economy, and the first such study to be conducted in the state since the mid-1990s. Recently, a number of factors—supply shortages, price volatility, and future price uncertainty—have combined to warrant a detailed analysis of energy-efficiency potential. Energy providers and policy makers can use the study's findings to better understand residential sector energy efficiency retrofits identified here as these can be cost-effective alternatives to conventional power supply.

This study assesses electric and natural gas energy-efficiency potential in existing residential buildings within the service territories of the four major investor-owned utilities (IOUs) in California: Pacific Gas and Electric Company (PG&E), Southern California Edison Company (SCE), Southern California Gas Company (SCG), and San Diego Gas and Electric Company (SDG&E). These utilities account for about 80 percent of the state's total electrical consumption and peak demand and 99 percent of natural gas consumption.

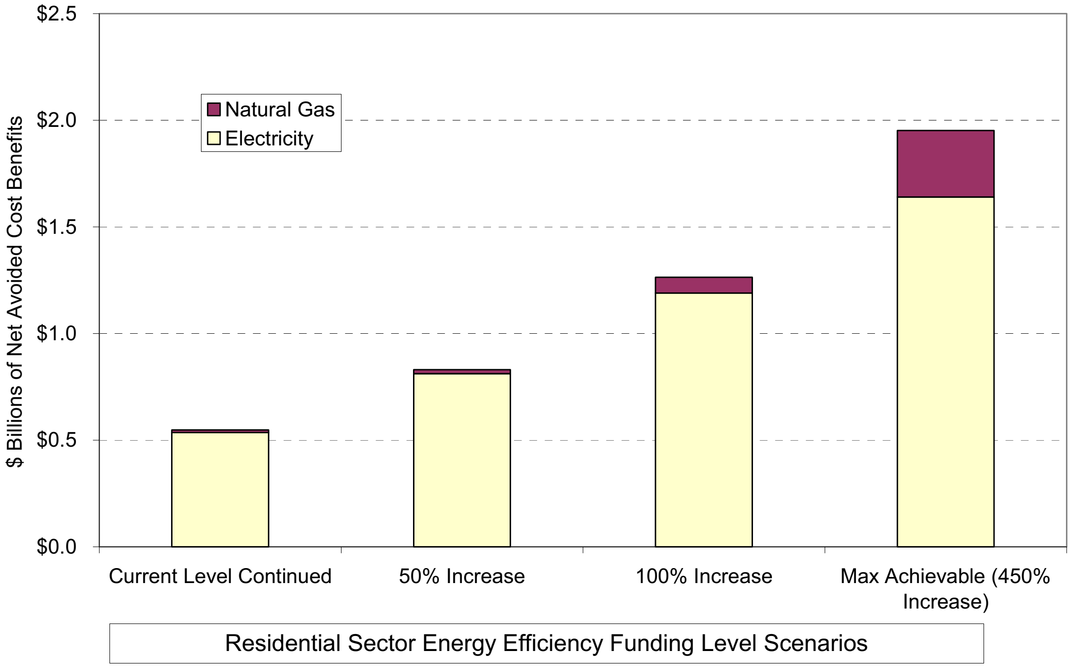
The study was managed by PG&E with review and input from the California Measurement Advisory Council (CALMAC) and the Market Assessment and Evaluation Statewide Team of Research Organizations (MAESTRO). It was funded through the public goods charge (PGC) for energy efficiency.

The study is designed to answer a number of research questions important to the planning of future residential energy-efficiency programs. These include:

- How much near-term residential sector energy-efficiency potential is there?
- What are the costs associated with this potential and acquiring savings through programs?
- How sensitive are potential estimates to factors such as avoided energy costs and electric rate increases?
- Are the current California residential energy-efficiency programs generally aligned with the estimated energy-efficiency potential?

Simulating different future funding levels, the study forecasts program energy and peak demand savings under three energy cost scenarios (Base, Low, and High). Under the base energy cost forecast, for example, net program peak savings potential ranges from roughly 385 megawatts (MW) under current funding to 1,773 MW if current funding is tripled. For natural gas, net program savings potential ranges from about 51 million therms (Mth) under current funding to 238 Mth under maximum achievable funding. As shown in Figure E-1, net financial savings to the state range from $550 million to $2.0 billion, depending on the funding level, with most of the savings resulting from electricity impacts. All funding scenarios constructed for the study are cost-effective (under our base energy cost scenario).

Figure E-1
Net Avoided-Cost Benefits of Residential Electric Efficiency Savings – 2002 to 2011



This report is one in a series examining energy-efficiency potential in the major IOU service territories. Two companion reports in this series address energy-efficiency potential in the commercial sector.[1] Future reports in this series will address new construction and other sectors.

E.1 WHY THIS STUDY?

Energy efficiency has been characterized for some time now as an alternative to energy supply options, such as conventional power plants that produce electricity from fossil or nuclear fuels. In the early 1980s, researchers developed and popularized the use of a conservation supply curve paradigm to characterize the potential costs and benefits of energy efficiency. Under this framework, technologies or practices that reduced energy use through efficiency were characterized as "liberating 'supply' for other energy demands" and could therefore be thought of as a resource and plotted on an energy supply curve. This energy-efficiency resource paradigm argues simply that the more economic energy efficiency, or "nega-watts" captured, the fewer power plants and less fuel required to power homes and businesses, the lower the associated environmental and human health impacts of energy consumption, the lower the exposure to future energy price volatility, and the lower the total energy bill paid by consumers.

After the restructuring of the electric sector in the mid-1990s, efforts to understand the remaining cost-effective savings potential and associated optimal program budgets declined. Following the 2000-2001 California energy crisis, however, policy makers and program implementers showed renewed interest in energy efficiency as an alternative energy resource, and they now require data and analyses to support decisions addressing the optimal mix of energy resources. This study covers part of the data and analyses needs by providing information on residential retrofit cost-effective energy-efficiency options.

E.2 STUDY SCOPE

This study focuses on assessing electric and gas energy-efficiency potential in the residential sector existing construction market for the major IOUs. This market includes both retrofit and replace-on-burnout measures; it explicitly excludes new construction and major renovation markets. The study assesses achievable potential savings over the mid-term, which we define as the next 10 years, and is restricted to energy-efficiency measures and practices that are presently commercially available. In addition, this study is focused on measures that could be relatively easily substituted for or applied to existing technologies on a retrofit basis. As a result, measures and savings that might be achieved through integrated redesign of existing energy-using systems, as might be possible during major renovations or remodels, are not included.

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[1] At the time of this publication, the *California Statewide Commercial Sector Energy Efficiency Potential Study* (Electric), July 2002, has been completed and can be downloaded from the CALMAC web site at www.calmac.org. A second commercial sector study, focusing on natural gas energy efficiency potential is due to be completed in January 2003.

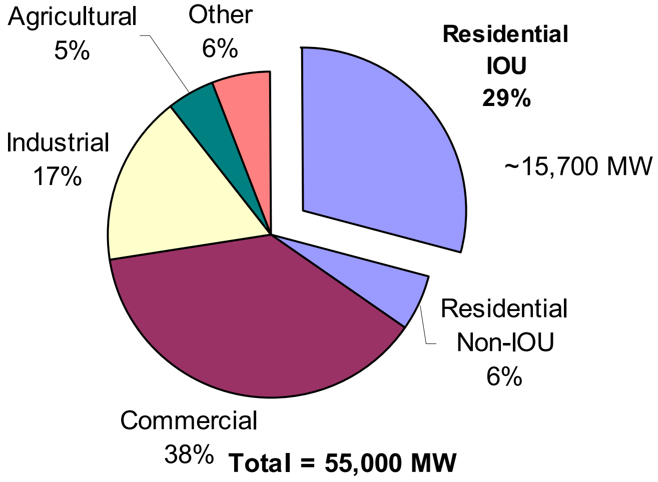
E.3 STUDY CONTEXT

To understand and estimate the potential for further efficiency improvements in California's energy use, it is important to understand how energy is used in the state. Energy and peak demand baseline data presented here and throughout this report are based on sector and end-use data from 2000, the latest detailed California Energy Commission data available at the time of this study. Thus, these figures do not account for the conservation-based reductions that occurred in 2001. While subsequent analyses have shown that considerable equipment-based energy savings were achieved in 2001, timing issues prevented the incorporation of 2001 energy-efficiency impacts into this report. Future updates of this study will incorporate the effects of the conservation and energy-efficiency actions taken since the beginning of 2001.

E.3.1 California Electricity Use

Electricity use in California has long been dominated by the residential, commercial, and industrial sectors. The residential sector makes up 35 percent of the recent summer peak demand (see Figure E-2) at about 19,000 MW of the total 55,000 MW peak demand in 2000. The residential sector of the major IOUs accounts for 29 percent of peak demand in the state, or roughly 15,700 MW.

Figure E-2
Contribution of Major IOU Residential Sector to Peak Demand*

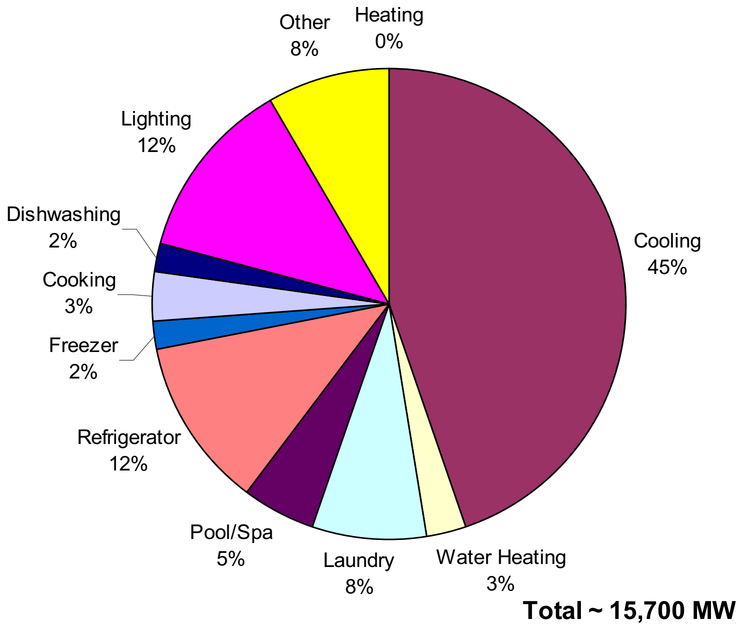


*Includes line losses

Source: Brown, R.E. and Jonathan G. Koomey, 2002 and California Energy Commission (CEC) 2001a. *2002 – 2012 Electricity Outlook*. P700-01-004.

As shown in Figure E-3, the principal end use that dominates residential sector peak demand is the air conditioning of buildings, accounting for 45 percent of the IOUs' peak, or roughly 7,000 MW, while lighting and refrigerators account for 12 percent each, or roughly 1,900 MW each.

Figure E-3
Breakdown of Residential IOU Summer Peak Demand by End Use



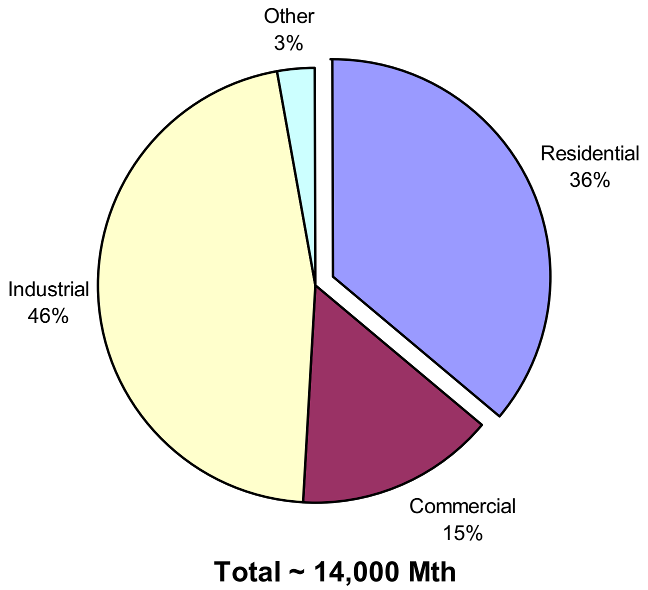
*Includes line losses. Source: CEC 2000 and XENERGY Inc. analysis.

At 84,000 GWh per year, the residential sector also makes up the second largest share (after commercial) of recent electricity consumption, representing 30 percent of the state's usage. The residential sector of the major IOUs accounts for 25 percent of total electricity consumption (thus, IOU customers account for 85 percent of total residential consumption in the state). Single-family homes account for the largest share of residential electricity usage in the IOU territories, at around 76 percent, or roughly 5,900 GWh.

E.3.2 California Natural Gas Use

Natural gas use in California is dominated by the residential and industrial sectors, combining to represent about 82 percent of statewide consumption. The residential sector makes up about 36 percent of annual gas usage, or about 5,000 Mth (see Figure E-4), with nearly all of this consumption being served by the state's IOUs. Single-family homes account for 74 percent of this residential usage, or roughly 3,700 Mth.

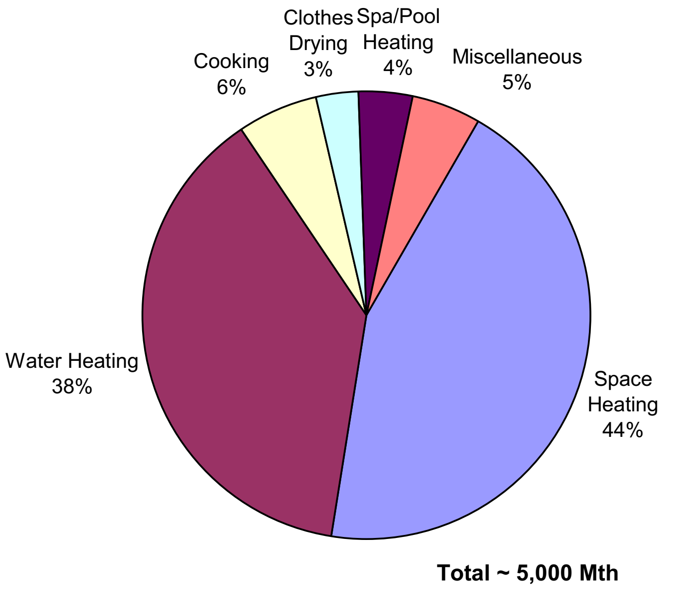
Figure E-4
Breakdown of Natural Gas Use by Sector



Source: CEC 2000. *California Energy Demand: 2000-2010.*

As shown in Figure E-5, the principal end uses dominating residential sector gas consumption are space heating and water heating, accounting for 82 percent of total residential usage, or roughly 4,100 Mth.

Figure E-5
Breakdown of Residential Gas Consumption by End Use



Source: CEC 2000. *California Energy Demand: 2000-2010.*

E.3.3 Historic Efficiency Programs

California is the nation's most efficient state in terms of per capita electricity consumption. Much of this is likely a direct result of the state's conscious efforts to fund and promote energy efficiency through programs and state standards. California has been a consistent leader in developing programs and policies aimed at increasing the efficiency with which energy is used in the state. Spending on programs, however, has increased and decreased, sometimes dramatically, over time. The cumulative effect of California's efficiency programs and standards over the past 25 years, according to CEC estimates, have resulted in savings of 9,000 MW and 2 million therms.

E.4 PROGRAM POTENTIAL RESULTS – 2002 TO 2011

For this study, we constructed four residential sector energy-efficiency funding scenarios. The first scenario is "Continued Current," which is intended to approximate a continuation of the current (2002) program funding level over the next 10 years. The next two scenarios, "50% Increase" and "100% Increase," represent 50- and 100-percent increases in total program funding over the "Continued Current" case, for the 10-year period. The last funding scenario is called "Max Achievable." This scenario represents our estimate of maximum achievable potential that could occur if all customers where made fully aware and knowledgeable of cost-effective efficiency measures and all incremental costs were paid for by the program. Costs under this scenario are about 450 percent higher for electric and roughly 300 percent higher for natural gas than under the "Continued Current" case and are reflective of a "direct-install" approach to implementing energy-efficiency projects.

E.4.1 Program Potentials – Electric Energy and Peak Demand Impacts

We forecasted program electric energy and peak demand savings under each funding scenario for a 10-year period beginning in 2002. We calibrated our energy-efficiency adoption model to actual program accomplishments over the period 1996 to 2000. Our estimated energy and peak demand program potentials are shown in Figures E-6 and E-7. Net program energy savings potential ranges from roughly 2,400 GWh under "Continued Current" funding to almost 9,800 GWh under "Max Achievable" funding. Program peak demand reductions range from 385 MW to 1,775 MW. "Continued Current" funding is similar to actual funding levels in 1999 and 2000, with incentives set at an average of 25 percent of measure costs. Under the "Continued Current" funding scenario, roughly 16 percent of our estimated economic potential[2] of 15,100 GWh would be captured.

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[2] Economic potential is defined in Section 4 and presented in Section 6.

Figure E-6
Program Electric Energy Savings Potential by Funding Level

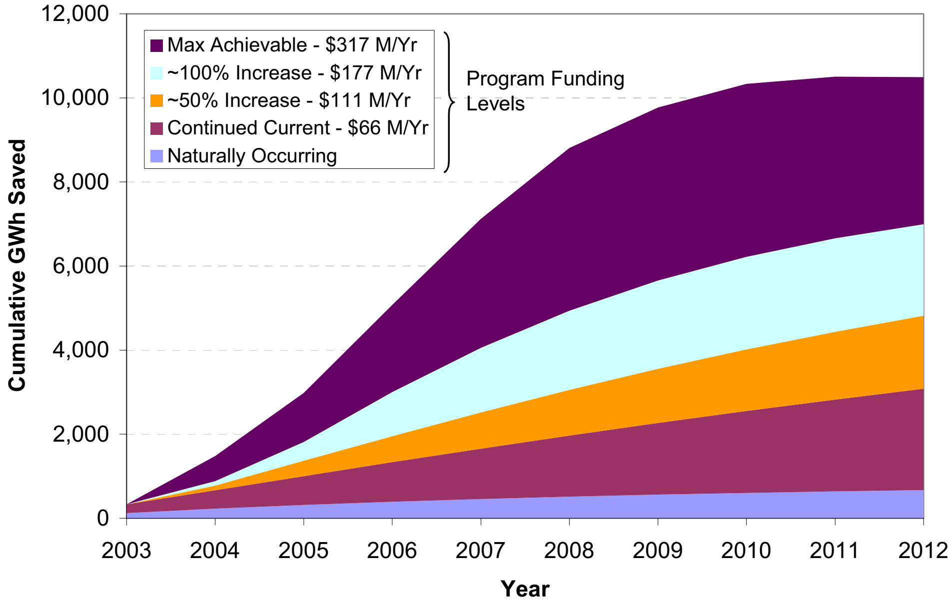
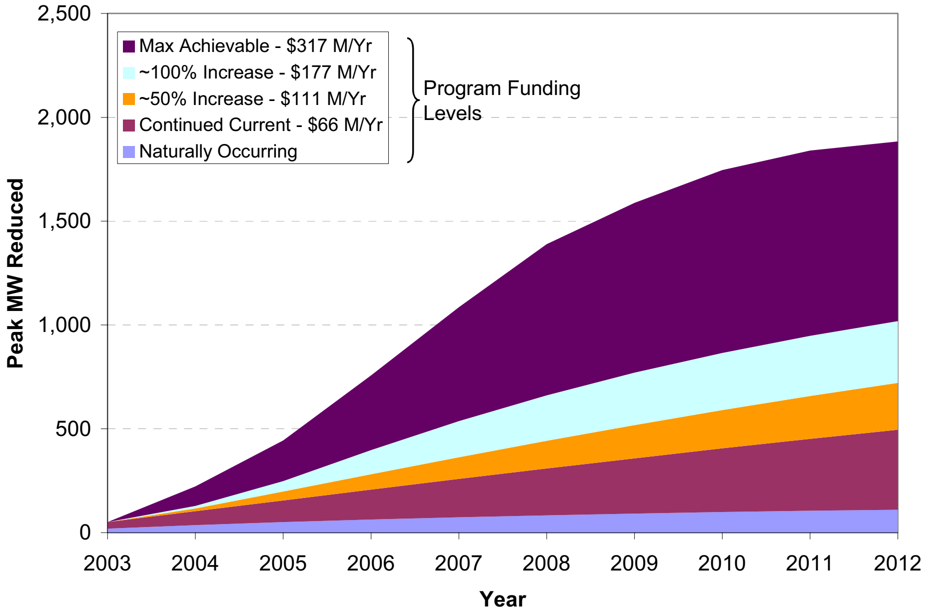


Figure E-7
Program Electric Peak Demand Reduction Potential by Funding Level



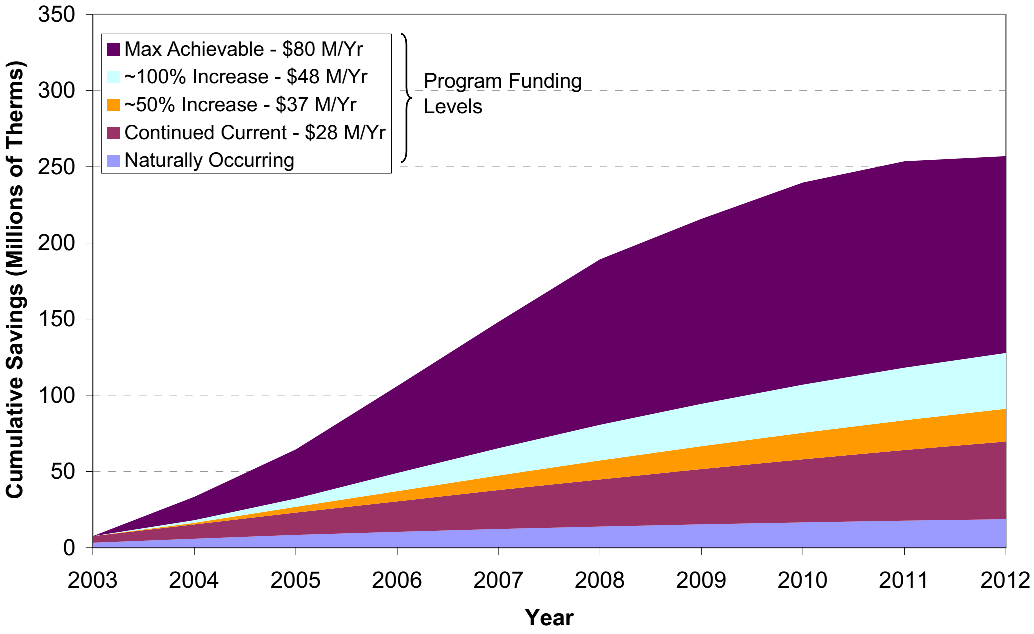
Expenditures for “Max Achievable” funding are roughly 450 percent greater than “Continued Current” and provide an estimate of maximum achievable potential in which incentives would cover 100 percent of measure costs, and marketing expenditures would make virtually all of the available market aware of efficiency measures. Under the "Max Achievable" scenario, we estimate that 65 percent of the economic potential could be captured.

The "50% Increase" and "100% Increase" are scenarios in which expenditures are 50 percent and 100 percent greater than the "Continued Current" expenditures. Incentive payments as a percent of incremental measure costs average approximately 40 percent and 55 percent under the "50% Increase" and "100% Increase" scenarios, respectively. Estimated energy savings under the "50% Increase" and "100% Increase" scenarios are approximately 4,150 and 6,300 GWh, respectively, and peak demand reductions are 610 and 900 MW.

E.4.2 Program Potentials – Natural Gas Impacts

Our estimated natural gas program potentials are shown in Figure E-8. Net program savings potential ranges from roughly 51 Mth under "Continued Current" funding to almost 240 Mth under "Max Achievable" funding. Under the "Continued Current" funding scenario, roughly 14 percent of our estimated economic potential of 370 Mth would be captured.

Figure E-8
Program Natural Gas Reduction Potential by Funding Level



E.4.3 Program Potential by End Use

Figure E-9 shows the composition of potential electric energy and peak demand savings under the Continued Current funding scenario[3]. The largest end use contributors to potential energy savings are lighting and refrigeration. The largest end use contributors to potential peak demand

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[3] Note that the end use composition of achievable potential, for both electric and natural gas savings, shifts somewhat across program funding scenarios (as can be seen in Sections 8.3.2 and 9.3.2 of this report).

reductions are air conditioning, refrigeration, and lighting. Lighting contributes a smaller share of peak demand savings potential relative energy savings potential, because only a small fraction of lights are typically on during the peak period (summer weekday afternoons).

Figure E-9
Program Electric Savings Potential by End Use (by 2012)

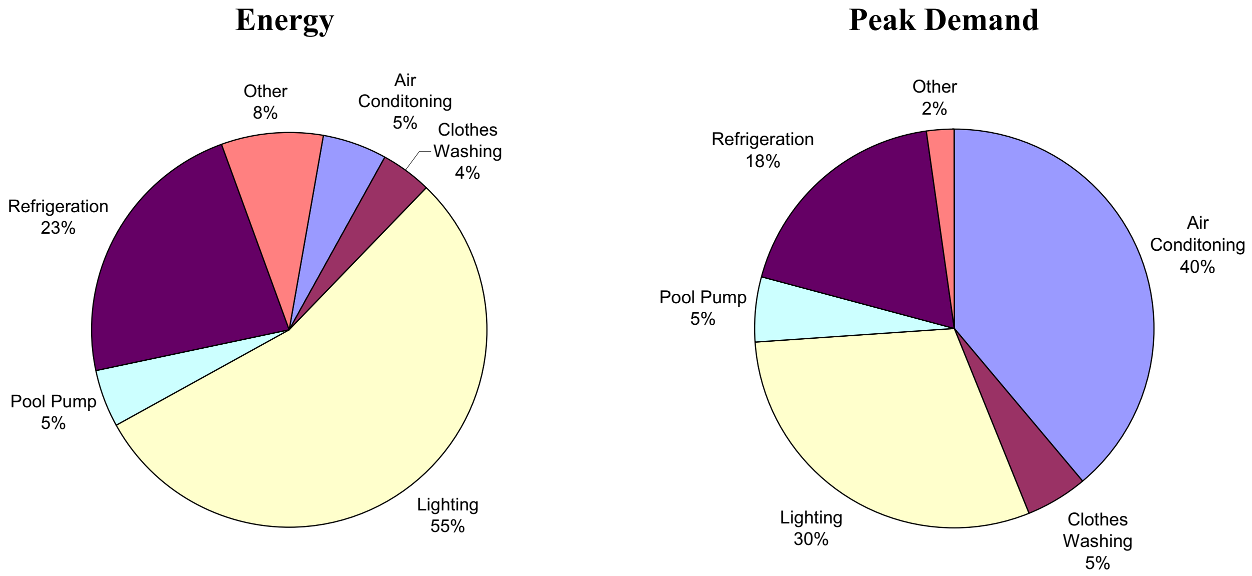
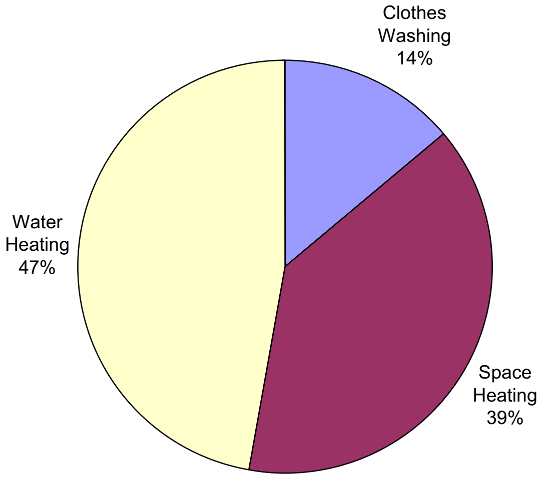


Figure E-10 shows the composition of potential natural gas savings under the Continued Current funding scenario. The largest end use contributors to potential energy savings are water heating and space heating, which are, by far, the largest gas end uses.

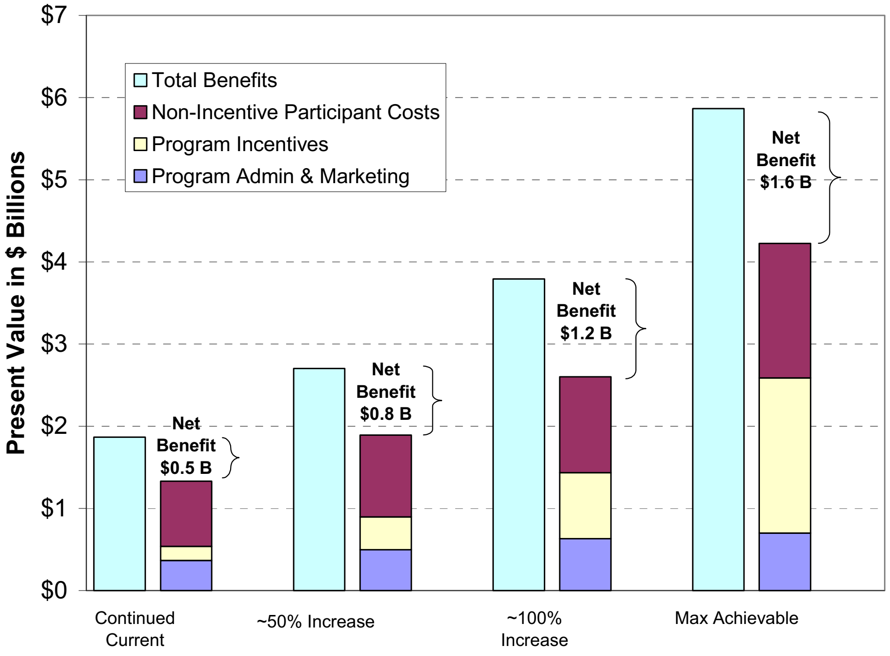
Figure E-10
Program Natural Gas Potential by End Use (by 2012)



E.4.4 Program Potentials – Benefits and Costs

The costs and benefits associated with the residential efficiency funding scenarios over the 10-year period are shown in Figures E-11 (electric) and E-12 (natural gas). As shown in Figure E-11, total electric program costs vary from $0.5 billion under the “Continued Current” scenario, to $0.9 billion under “50% Increase,” to $1.4 billion under “100% Increase,” to $2.6 billion under “Max Achievable.” Total electric avoided-cost benefits range from $1.9 billion under “Continued Current” to $5.9 billion under “Max Achievable.” Net avoided-cost benefits, which are the difference between total avoided-cost benefits and total resource costs (which include participants’ costs), range from $0.5 billion to $1.6 billion.

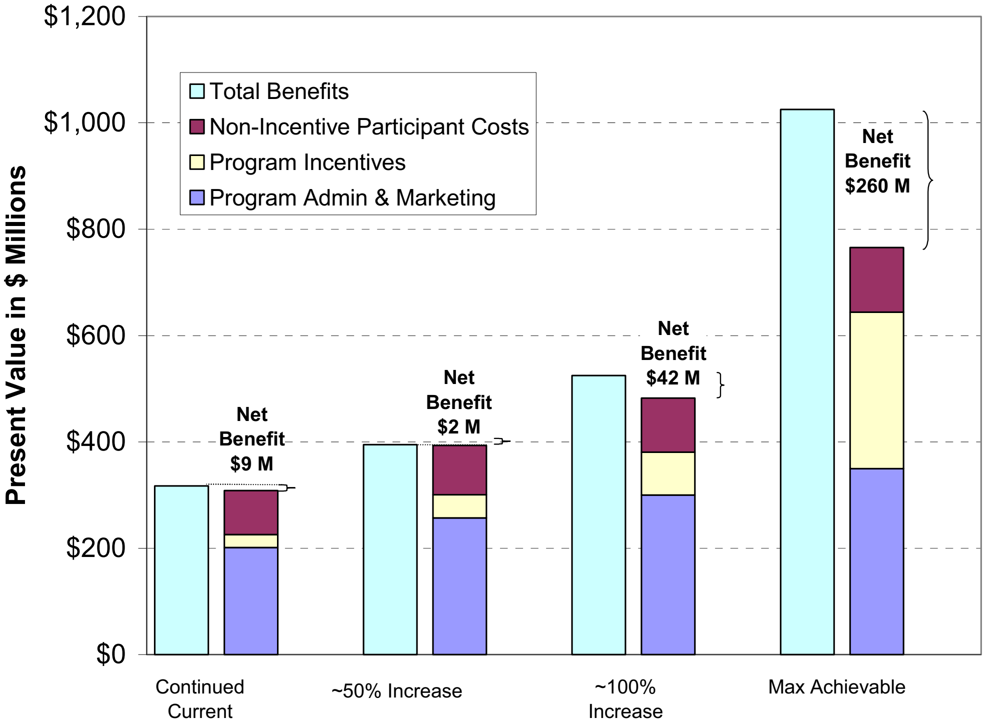
Figure E-11
Costs and Benefits of Residential Electric Efficiency Savings – 2003 to 2012*



*Value of benefits and costs over life of measures, nominal discount rate = 8 percent, inflation rate = 3 percent.

As shown in Figure E-12, total natural gas program costs vary from about $220 million under the “Continued Current” scenario, to about $590 million under “Max Achievable.” Total avoided-cost benefits range from about $320 million under “Continued Current” to $1.0 billion under “Max Achievable.” Net avoided-cost benefits range from $12 million to $312 million. The large increase in net benefits between the “100% Increase” scenario to the “Max Achievable” scenario indicates that relatively large incentives may be required to overcome market barrier thresholds involving natural gas energy-efficiency measures.

Figure E-12
Costs and Benefits of Residential Natural Gas Efficiency Savings – 2003 to 2012*



*Value of benefits and costs over life of measures, nominal discount rate = 8 percent, inflation rate = 3 percent.

As shown in Table E-1, all of the funding scenarios are cost-effective based on the total resource cost test, which is the principal test used in California to determine program cost effectiveness.

Table E-1
TRC by Funding Scenario

Funding Scenario	Electric Benefit-Cost Ratio	Natural Gas Benefit-Cost Ratio
“Continued Current”	1.40	1.03
“50% Increase”	1.43	1.00
“100% Increase”	1.46	1.09
“Max Achievable”	1.39	1.34

E.4.5 Program Potentials Under High and Low Energy Cost Scenarios

The preceding results are based on base-case forecasts of retail energy rates and avoided costs for energy supply, transmission, and distribution. The assumptions for the base energy cost forecast data are provided in Section 5 of this report. The avoided costs follow those approved by the CPUC for use in the IOUs’ 2002 program cost-effectiveness analyses. The base retail rate forecast follows the California Energy Commission's residential retail rate forecast published in July 2002. In recognition of the considerable uncertainty in both future retail and wholesale electricity and natural gas costs, we constructed two alternative energy cost scenarios. One scenario captures a lower cost future and the other a higher cost future.

Program potential estimates under the different cost scenarios and funding levels are presented in Table E-2. Estimates of net electric program potentials under Low energy costs are roughly two-thirds of those estimated under the Base energy costs. Electric program potentials under the High scenario average about 20 percent higher than under the Base energy costs. For natural gas, program potentials under the Low energy costs are less than half of the potentials under the Base energy costs, while program potentials under the High energy costs are about 25 percent higher than under the Base energy costs.

Table E-2
Program Potentials Under Different Energy Cost Scenarios

Savings Type	Energy Cost Scenario	Funding Level			
		Continued Current	~50% Increase	~100% Increase	Max Achievable
Net GWh Savings	Base	2,413	4,149	6,327	9,826
	Low	1,269	2,552	4,800	6,023
	High	3,371	5,205	6,832	9,522
Net Mth Savings	Base	51	73	109	238
	Low	14	15	39	157
	High	86	83	153	275

For both electricity and natural gas, benefit-cost ratios increase considerably under the High energy cost scenario by over 20 percent for electricity and over 50 percent for natural gas. Under the Low energy cost scenario, benefit-cost ratios are generally below 1, indicating that the analyzed programs would not be cost effective under a much lower energy cost future.

E.5 MOVING FORWARD: A NEW APPROACH TO RESOURCE PLANNING

Although the preceding findings represent a critical first step in the process of understanding the resource potential of energy efficiency in the residential sector, it is important to remember that they are based on static avoided-cost forecasts and do not consider synergistic interactions among various efficient technologies nor efficiency options for new residential construction. Use of static avoided costs does not provide adequate information for determining the optimal mix of all possible resources (e.g., energy efficiency, demand response/load management, distributed generation, conventional supply, renewable energy, etc.). As energy-efficiency and conservation markets continue to evolve, enhancing the availability, affordability, and accessibility of efficient products and services, we can expect the incremental costs of both products and services to continue to decrease.

To determine the optimal mix of resources, a broader analytical framework is necessary. Developing such a framework was not a part of the current study; however, efforts to develop such a framework are being considered.

Besides completing additional studies to estimate achievable efficiency potential for other sectors, we believe new analytical methods are necessary to improve upon strategic resource planning processes developed during the period of integrated resource planning in the early 1990s. Research is needed to determine how investments in demand- and supply-side resources should be optimized in California given the events of the past 2 years. What is needed is an approach that builds from the lessons learned from both the integrated resource planning period of the late 1980s and early 1990s and the market-based experiments of the last 5 years. Such an approach would require supply-side forecasts and integration analyses that explicitly incorporate price uncertainty, price volatility, and probabilities of future energy "events" such as supply shortages and price spikes.

1

INTRODUCTION

1.1 ABOUT THIS REPORT

This study assesses electric and gas energy-efficiency potential in existing residential households within the service territories of the four major investor-owned utilities (IOUs) in California: Pacific Gas and Electric Company (PG&E), Southern California Edison Company (SCE), San Diego Gas and Electric Company (SDG&E) and Southern California Gas (SCG); referred to hereafter as the "major IOUs." The study is managed by PG&E, with review and input from the California Measurement Advisory Council (CALMAC) and the Market Assessment and Evaluation Statewide Team of Research Organizations (MAESTRO). The study was funded through the public goods charge (PGC) for energy efficiency.

This report is the second in a planned series of reports on energy-efficiency potential in the major IOU service territories.[1] Each report is designed as a standalone report and contains overall background and contextual information as well as information specific for that study. Other reports in the series address energy-efficiency potential in the commercial sector; future reports will address new construction in the residential and other sectors.

This report provides both detailed and aggregated estimates of the costs and savings potential of energy-efficiency measures for existing residential households. In addition, it provides forecasts of savings and costs associated with different levels of program funding over a 10-year period. Program savings and cost-effectiveness estimates are also evaluated under several possible future scenarios that take into account uncertainty in electricity and natural gas rates and wholesale energy costs.

Prior to the current work, no comprehensive study of energy-efficiency potential had been conducted in California since the mid-1990s. Since that time, a number of factors have combined to warrant detailed analysis of energy-efficiency potential in the State.

1.2 WHY AN ENERGY-EFFICIENCY POTENTIAL STUDY?

Energy-efficiency potential studies were popular throughout the utility industry from the late 1980s through the mid-1990s. This period coincided with the advent of what was called least-cost or integrated resource planning (IRP). IRP was, and still is in some states, required as a process whereby utilities could consider both supply-side and demand-side resource options to meet future energy needs (EPRI 1991). Energy-efficiency potential studies became one of the

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[1] At the time of this publication, the *California Statewide Commercial Sector Energy Efficiency Potential Study* (Electric), July 2002, has been completed and can be downloaded from the CALMAC web site at www.calmac.org. A second commercial sector study, focusing on natural gas energy-efficiency potential, is due to be completed in January 2003.

primary means of characterizing the resource availability and value of energy efficiency within the overall resource planning process. Like supply-side resources, energy-efficiency resources can be characterized in terms of their costs and availability—on both an hourly basis throughout a typical year and across years into the future.

Although IRP was abandoned in California with the advent of electric industry restructuring in the State, interest in the resource value of energy efficiency soared when wholesale energy prices spiked out of control in 2000 and 2001. Whether part of formal IRP or to help policy makers and program planners carry out more effective programs because of energy price shocks, energy-efficiency potential studies help to answer important questions, for example:

- How much near-term energy-efficiency potential is there?
- Is potential running out in some areas or remaining untapped in others?
- What are the costs associated with this potential?
- How much savings can be acquired through programs?
- How sensitive are potential estimates to uncertainty in avoided costs and retail prices?

1.3 STUDY SCOPE

As noted above, the study focuses on assessing electric and natural gas energy-efficiency potential in the existing construction market of the residential sector within the territories of the major IOUs. This market includes both retrofit and replace-on-burnout measures, and it excludes new construction and major renovation markets. The analysis methodology is somewhat different in estimating energy-efficiency potential in new versus existing buildings. In addition, the size of the residential new construction market, at roughly 12,300 GWh over the next 10 years, is significantly smaller than that of existing residential construction, estimated to be approximately 79,800 GWh over the same period.[2] As stated above, a future study will address energy-efficiency potential for new construction in the residential sector.

The study is limited to assessing potential energy savings from installation of energy-efficiency measures, as these measures are of primary interest to IOU program planners. The study does not address the potential savings from customer behavioral changes, such as increased conservation. While behavioral changes can lead to reductions in energy consumption, as demonstrated by Californians' response to the energy crisis of 2001, it is not clear how permanent and dependable such reductions will be.

The study is focused on assessing potential savings over the near term, which we define for this report as the next 10 years. Consistent with this mid-term focus, the study is restricted to energy-efficiency measures and practices that are presently commercially available. These are the measures that are of most immediate interest to energy-efficiency program planners. The study data, framework, and models can be easily leveraged in the future to add estimates of potential

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[2] XENERGY Inc. *California's Secret Energy Surplus: the Potential for Energy Efficiency,* prepared for The Energy Foundation. September 2002.

for emerging technologies. In addition, the scope of this study is focused on measures that could be relatively easily substituted for or applied to existing technologies on a retrofit basis. As a result, measures and savings that might be achieved through integrated redesign of existing energy-using systems, as might be possible during major renovations or remodels, are not included. This is another area in which the current results can be expanded upon.

As discussed in Section 2, the effects of the unprecedented changes in energy consumption and behavior among consumers and businesses in California during 2001 were not well enough understood to incorporate into the study at the time that the primary analyses were conducted. Therefore, the estimates of potential presented in this study do not reflect the unusual level of energy conservation that occurred in 2001; instead, this report uses 2000 as its base year. Future updates of this study may incorporate revised energy consumption baseline information that accounts for any permanent changes in conservation resulting from the recent energy crisis.

1.4 ENERGY EFFICIENCY AS AN ENERGY RESOURCE

Energy efficiency has been characterized for some time now as an alternative to energy supply options. In the early 1980s, Arthur Rosenfeld,[3] Roger Sant,[4] Amory Lovins, and Alan Meier,[5] among others, conducted much of the initial work in this area by developing and applying conceptual frameworks for understanding and formally characterizing energy efficiency as an energy resource. The term "nega-watt" was coined to emphasize that a kilowatt-hour saved through efficiency was a kilowatt-hour that would not have to be produced and delivered by an existing or new power plant. Meier and Rosenfeld developed and popularized the use of a conservation supply curve paradigm to characterize the potential costs and benefits of energy conservation and efficiency in the early 1980s. Under this framework, technologies or practices that reduced energy use through efficiency were characterized as "liberating 'supply' for other energy demands" and could therefore be thought of as a resource and plotted on an energy supply curve.[6] In short, the energy-efficiency resource paradigm argued simply that the more energy efficiency, or nega-watts produced, the fewer new plants society would need to satisfy consumption.

1.5 TYPES OF POTENTIAL

Like any resource, there are a number of ways in which the energy-efficiency resource can be estimated and characterized. Definitions of energy-efficiency potential are in some ways analogous to definitions of potential developed for finite fossil fuel resources like coal, oil, and natural gas. For example, fossil fuel resources are typically characterized along two primary dimensions: the degree of geologic certainty with which resources may be found and the likelihood that extraction of the resource will be economic. This relationship is shown conceptually in Figure 1-1.

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[3] Rosenfeld provides an excellent and interesting historical summary of the early days of developing estimates of energy-efficiency potential, beginning in the 1970s, in Rosenfeld 1999.

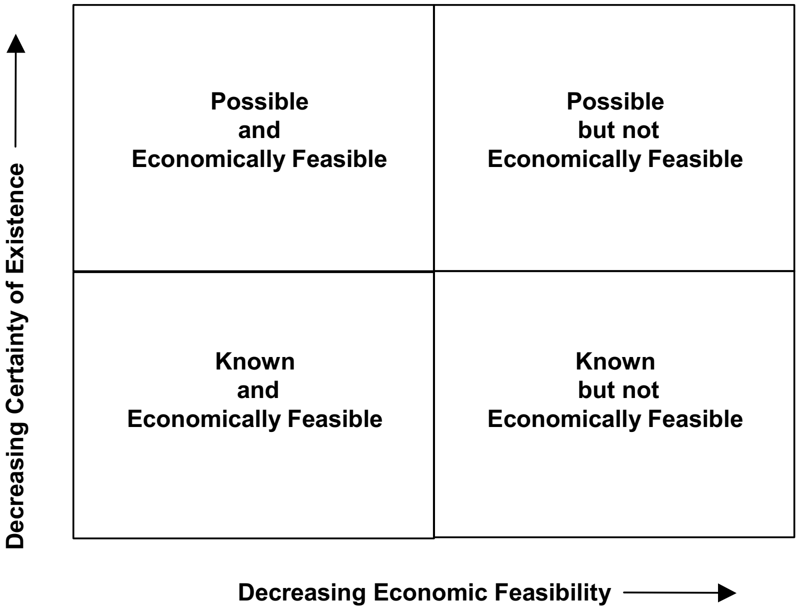
[4] Sant is often credited with coining the terms "least cost energy services" and "cost of conserved energy."

[5] See also Lovins et al. 1996 and Meier 1982

[6] Energy-efficiency supply curves are described in more detail later in this section.

As illustrated by the lower left block in the figure, some fossil resources are known with respect to their location and size (usually from drilling samples) and are economically feasible to extract. These are usually referred to as proven reserves. Other resources are known but not economic to extract. Outside of the known resources are resources that are possible but not well known. Thus, all other quadrants of the figure are possible resources. However, both the certainty of knowledge about existing resources and their economic viability of extraction can change quickly, for example, in response to wide swings in global oil prices. Thus, the conceptual boundaries in the figure have proven to be very amorphous and dynamic over time.

Figure 1-1
Conceptual Framework for Estimates of Fossil Fuel Resources



Source: Healy et al. 1983.

Previous energy-efficiency potential studies have defined several different types of energy-efficiency potential. Among the most common of these terms are technical, economic, achievable, program, and naturally occurring potential. These potentials are shown conceptually in Figure 1-2 and described below.

The first set of energy-efficiency potential studies focused primarily on identifying what is often called technical potential.[7] **Technical Potential** was usually defined as the complete penetration of all measures analyzed in applications where they were deemed technically feasible from an engineering perspective. These studies sometimes included other efficiency measures that were commercialized and available; however, sometimes studies include emerging technologies that are considered feasible but may not be commercialized. In either case, technical potential is analogous to the possible resource definition used for fossil fuels.

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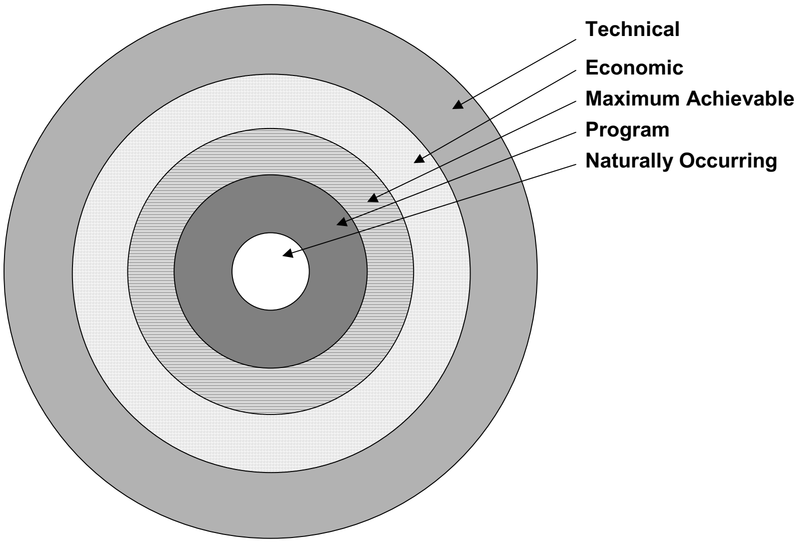
[7] For example, see XENERGY 1989, XENERGY 1990, and XENERGY 1992.

Figure 1-2
Relative Relationship of Energy-Efficiency Potential Definitions



As more studies began to be employed in utility IRP processes in the mid-1980s and early 1990s, many authors formally added the concept of economic potential to their lexicon. **Economic Potential** was typically used to refer to the technical potential of those energy conservation measures that were cost-effective when compared to supply-side alternatives.[8] Economic potential takes into account the fact that many energy-efficiency measures cost more to purchase initially than do their standard-efficiency counterparts.

In addition to these concepts, some studies, such as this one, include another: maximum achievable potential. **Maximum Achievable Potential** is defined as the amount of economic potential that could be achieved over time under the most aggressive program scenario possible.[9] Experience with efficiency programs shows that maximum achievable potential will always be less than economic potential for two key reasons. First, even if 100 percent of the extra costs to customers of purchasing an energy-efficient product are paid for through program financial incentives such as rebates, not all customers will agree to install the efficient product. Second, delivering programs to customers requires expenditures for administration and marketing beyond the costs of the measures themselves. Marginally cost effective projects may no longer have benefits that exceed full costs when these costs are considered.

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[8] *Economic potential* has been defined differently in different studies. For example, in the traditional IRP framework, economic potential is often defined based on the marginal cost of building and running new power plants. These studies usually take a utility or societal perspective in defining what is economic. Other studies sometimes define economic potential from the consumer's perspective, that is, based solely on the direct costs and benefits to consumers.

[9] Note that this definition only applies to voluntary programs. Mandatory government efficiency standards, such as California's Title 24 and Title 20 standards, can and do achieve savings equal to economic potential for the equipment or consumption levels regulated.

Although the potentials defined above are important for establishing the amount of the efficiency resource that is theoretically available, planners and policymakers are most interested in knowing the amount of savings or resource reduction that could occur in response to a particular set of programs or policies, rather than the maxima possible in theory. As a result, many energy studies began in the 1990s to formally estimate what is sometimes called program potential. **Program potential** usually refers to the amount of savings that would occur in response to one or more specific market interventions. Because program potential will vary significantly as a function of the specific type and degree of intervention applied, it is often developed for multiple scenarios (e.g., “moderate” intervention versus “aggressive” intervention). Savings associated with program potential are savings that are projected beyond those that would occur naturally in the absence of any market intervention.

The final category of potential used in this study is one that others and we refer to as naturally occurring potential. **Naturally occurring potential** is often used to refer to the amount of savings estimated to occur as a result of normal market forces, that is, in the absence of any utility or governmental intervention.

1.6 REPORT ORGANIZATION

The remainder of this report is organized as follows:

- Section 2 presents an overview of current and projected energy use in California
- Section 3 summarizes historic energy-efficiency expenditures and savings in California
- Section 4 presents the methodologies used for this study
- Section 5 describes the scenarios for which estimates of potential are developed
- Section 6 presents technical and economic potential results for electricity
- Section 7 presents technical and economic potential results for natural gas
- Section 8 presents program potential results for electricity
- Section 9 presents program potential results for natural gas
- Section 10 summarizes the results and proposes steps for further research
- Section 11 lists the sources used to support this research.

The following appendices are also included:

- Appendix A – Data Development
- Appendix B – Economic Inputs (avoided costs, rates, discount rates)
- Appendix C – Measure Inputs for Electricity
- Appendix D – Measure Inputs for Natural Gas
- Appendix E – Household and Time-of-Use Inputs (e.g. load shapes)

- Appendix F – Non-Additive Measure-Level Results for Electricity
- Appendix G – Non-Additive Measure-Level Results for Natural Gas
- Appendix H – Segment and End Use Summary Electric Potentials
- Appendix I – Segment and End Use Summary Natural Gas Potentials
- Appendix J – Achievable Program Scenarios
- Appendix K – Summary of PY2001 Residential IOU Programs
- Appendix L – DSM ASSYST Model Documentation.

2

STUDY CONTEXT: ENERGY USE IN CALIFORNIA

This section provides background data and discussion on electric and natural gas use in California. We begin by presenting historical use for the State as a whole and then focus on characterizing residential use within the major investor-owned utilities (IOUs). Our analysis of baseline consumption focuses on the year 2000. We use 2000 as our reference year for two reasons. First, 2000 is the most recent year for which the California Energy Commission (CEC) has end-use level data for use as the baseline of our energy-efficiency potential estimates. Second, 2001 was an unusual year with respect to energy consumption and peak demand because of the conservation response to the 2001 energy crisis, and at the time of this analysis, this response had not been fully analyzed.

California has long been one of the fastest growing states in the United States. Its population has grown from 20 million in 1970 to 34 million in 2000. The State's gross state product increased over the same period from $112 billion[1] to $1,260 billion. Because energy use is correlated with population and economic growth, the State's energy use has also increased over the past 40 years; however, the degree of correlation is reduced through increased energy efficiency.

2.1 ELECTRICITY USAGE

2.1.1 Recent Overall Electric Use and Past Trends

The State's energy consumption and percent change in annual electricity use since 1960 are shown in Figure 2-1. In the 13 years preceding the country's first energy crisis in 1973, electricity use in California almost tripled, from 50,000 GWh per year to almost 150,000 GWh per year. The annual rate of electricity growth during these years averaged over 5 percent per year. Over the following quarter century, the average rate of growth of electricity was significantly reduced in California. Electricity growth averaged 3.2 percent per year in the 1980s and only 2.2 percent per year in the 1990s.[2] In fact, while per capita electricity consumption has increased by 50 percent since 1973 in the United States[3] as a whole; remarkably, per capita use in California has been held constant. As a result, California is the nation's most efficient state in terms of per capita electricity consumption. As discussed in Section 3, much of this is likely a direct result of the State's efforts to fund and promote energy efficiency through programs and improve state standards, as well as milder weather.

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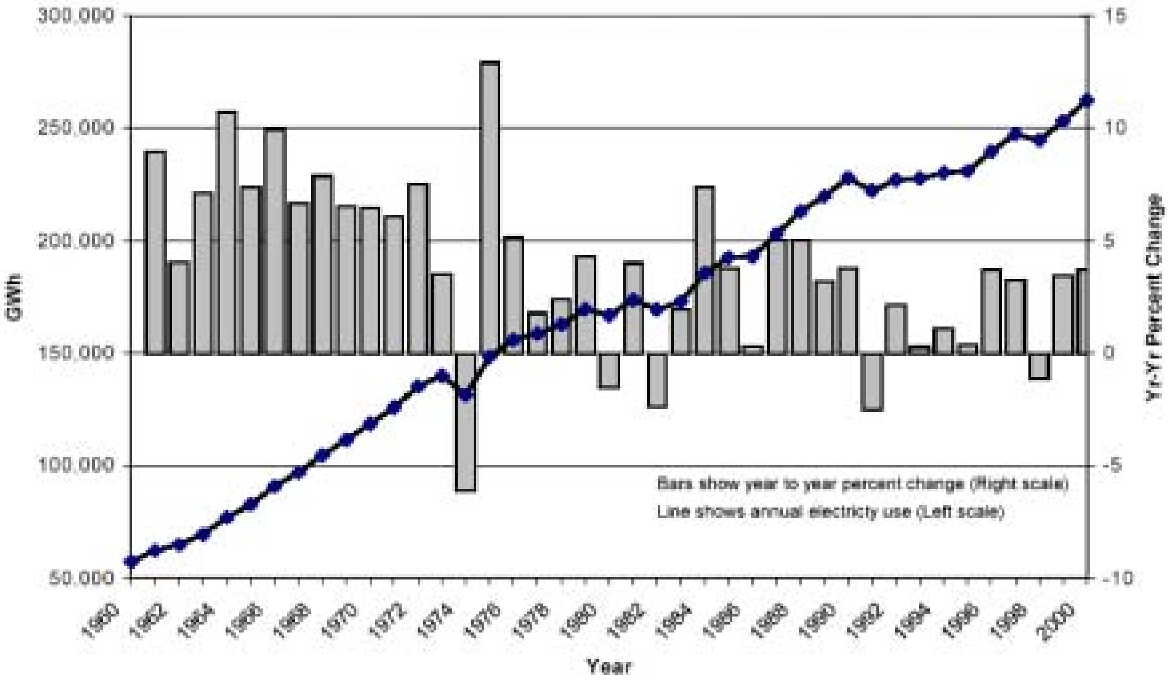
[1] Source: U.S. Department of Commerce, Bureau of Economic Analysis.

[2] Brown, R.E. and Jonathan G. Koomey, 2002. *Electricity Use in California: Past Trends and Present Usage Patterns*, Review Draft, Lawrence Berkeley National Laboratory, LBNL-47992. January.

[3] Note that although per capita use in the U.S. has grown significantly since the 1973 energy crisis; the 1.6 percent rate of growth was well below the 5 percent rate of annual growth in the 15 years preceding the 1973 crisis.

Figure 2-1
California Electricity Consumption: 1960 – 2000*

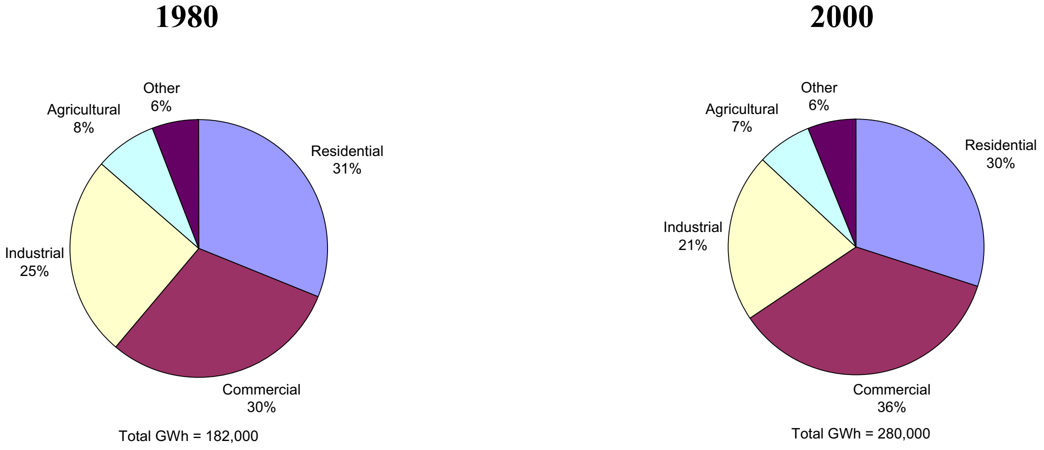


*Excludes line losses from transmission and distribution of electricity, estimated to be 8.5 percent for this study. Source: California Energy Commission (CEC) 2001a. *2002 – 2012 Electricity Outlook*. P700-01-004.

To understand and estimate the potential for further efficiency improvements in California's electrical energy use, it is important to understand how electricity is used in the State. Two key dimensions of electricity use are sector and end use. Sector refers to the type of customer using electricity (e.g., commercial, residential, etc.), while end use refers to the service desired by the electricity (e.g., lighting or cooling).

Electricity use in California has long been dominated by the residential, commercial, and industrial sectors, as shown in Figure 2-2. The commercial sector makes up the largest share of recent electricity consumption, representing 36 percent of the State's usage, followed by the residential sector at 30 percent, and the industrial sector at 21 percent. The agricultural sector makes up 7 percent of its electricity consumption, while other customers, such as transportation and street lighting, accounted for the remaining 6 percent. Since 1980, the commercial sector has grown most rapidly, averaging 3 percent per year, while the industrial sector grew most slowly, averaging just 1.3 percent per year. Residential use grew by 2 percent per year over the same period.

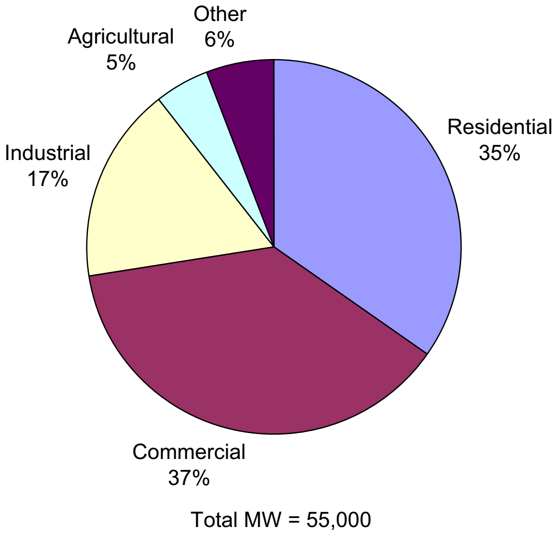
Figure 2-2
Breakdown of California Electricity Use by Sector: 1980 and 2000



Source: Brown, R.E. and Jonathan G. Koomey, 2002 and CEC 2000. *California Energy Demand: 2000-2010*.

California is a summer peaking state; that is, the maximum amount of electricity needed occurs during the hottest days of the summer. When we look at peak electrical demand in the State, shown in Figure 2-3, we see that the commercial and residential sectors are even more significant, accounting for a combined 73 percent of peak load in 2000. Rates of growth for peak demand by sector have been similar to those for electricity consumption over the past 20 years.

Figure 2-3
California Peak Electricity Demand by Sector: 2000*



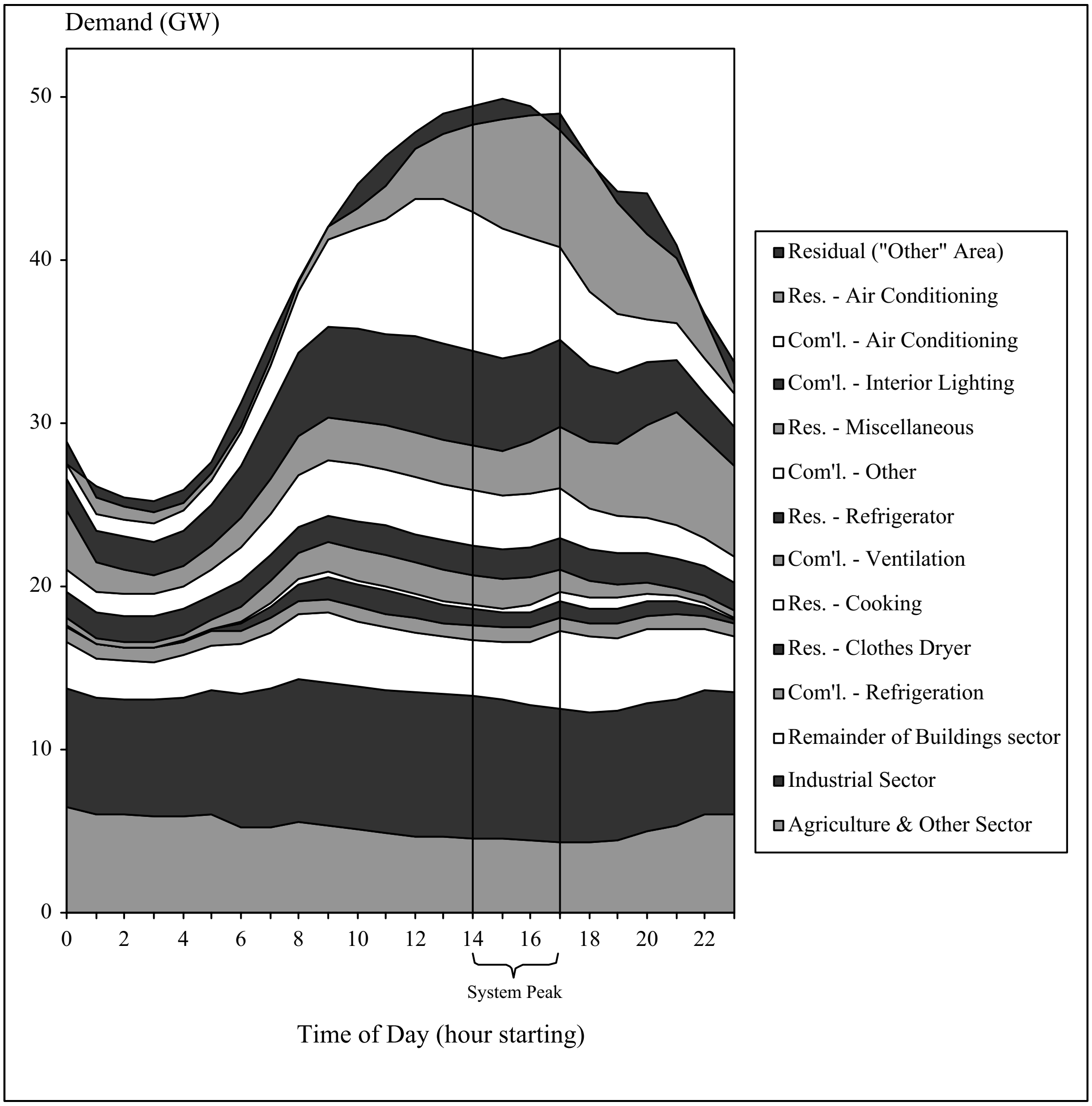
*Includes line losses.

Source: California Energy Commission (CEC) 2001a. *2002 – 2012 Electricity Outlook*. P700-01-004.

Electricity is used within each sector for a wide variety of purposes. For example, in the residential as well as the commercial sectors, building occupants use electricity to obtain lighting, thermal comfort, refrigeration, and other services. In the industrial sector, electricity is used primarily to manufacture products. Agricultural electricity use provides for the pumping of water for crops and refrigeration for dairies.

Figure 2-4 shows the largest contributors to peak demand in California. Electricity to provide the cooling and ventilation of residential and commercial buildings accounts for the largest share of peak demand, roughly one-third of total, or approximately 16,000 MW of peak demand in 1999.

Figure 2-4
Largest Contributors to California Peak Demand



Source: Brown and Koomey 2002.

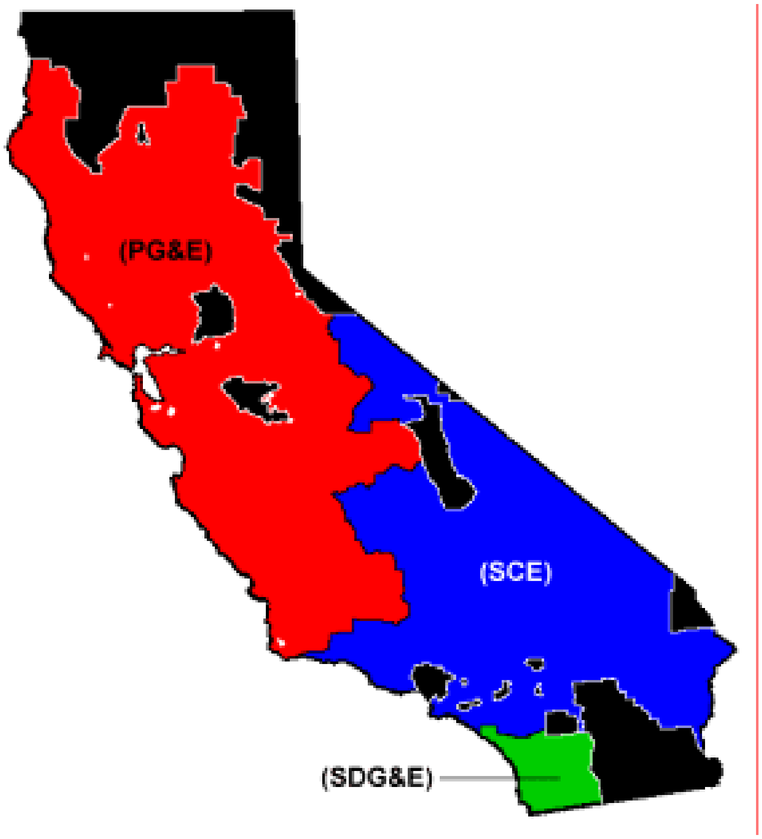
Commercial lighting makes up the next single largest end-use share of peak demand at over 5,000 MW. Other key contributors to peak demand include industrial manufacturing (roughly 6,000 MW) and residential lighting and refrigerators (5,000 to 6,000 MW each).[4]

2.1.2 In-Scope Residential Sector Electric Use for the Major IOUs

The scope of this study includes residential energy use California, including electric use in the territories of PG&E, SCE, and SDG&E. These territories are shown, along with those of the other utilities in the State, in Figure 2-5. The three major electric IOUs account for about 82 percent of the State's total electrical consumption.

The residential sector is second-largest contributor to both the State's electrical energy usage and peak demand. Residential customers within the service territories of the major IOUs accounted for approximately 15,700 MW of peak demand in 2000, which represented about 83 percent of the total residential demand in the State (see Figure 2-6). In 2000, energy consumption for the residential sector in the major IOU territories was roughly 71,000 GWh (including line losses).

Figure 2-5
California IOU Service Territory Map



Source: California Independent System Operator website: http://www1.caiso.com/aboutus/infokit/map/

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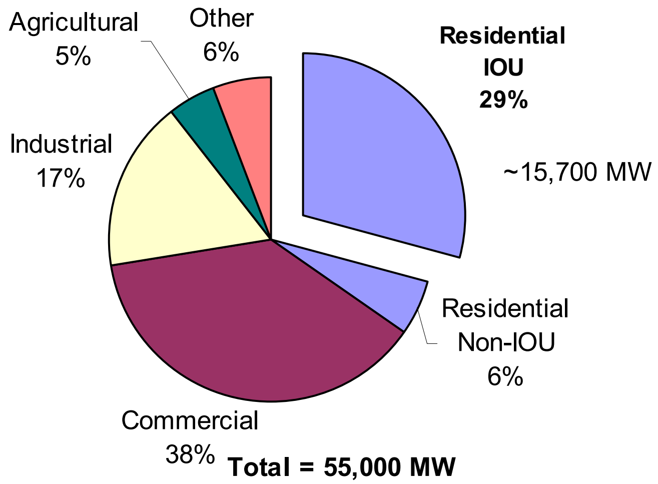
[4] Figures cited are from Brown and Koomey's (2002) analysis of CEC and FERC data for 1999.

Figure 2-6
Contribution of Major IOU Residential Sector to Peak Demand*

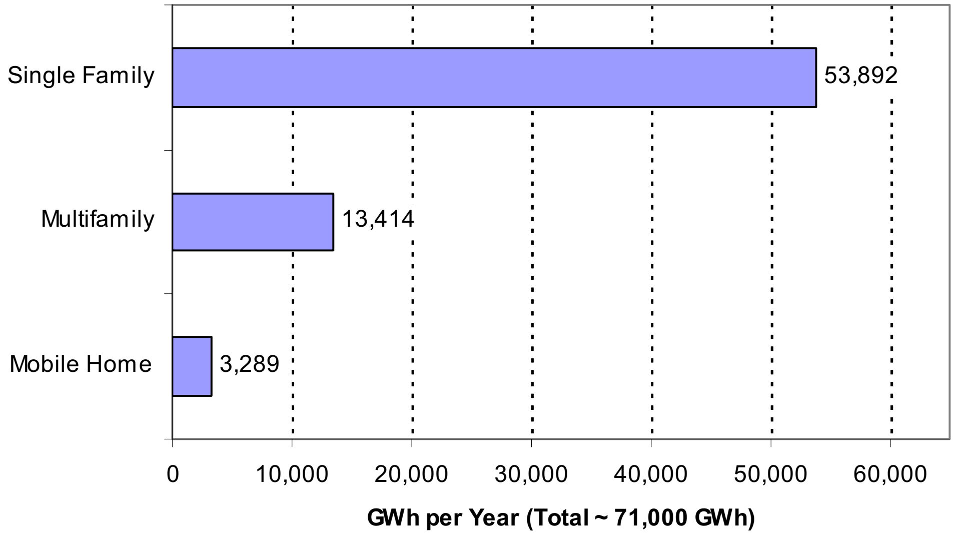


*Includes line losses

Source: Brown, R.E. and Jonathan G. Koomey, 2002 and California Energy Commission (CEC) 2001a. *2002 – 2012 Electricity Outlook*. P700-01-004.

Electricity use within the residential sector can be analyzed in several ways. Figures 2-7 through 2-9 summarize characteristics of residential electricity usage for customers in the service territories of the major IOUs. Figure 2-7 summarizes residential energy usage by residential building type. Single-family homes account for the largest share of electricity usage, at over 75 percent, or almost 54,000 GWh. The next largest energy-consuming building type is multi-family complexes, which accounts for 19 percent of all residential usage, or 13,400 GWh.

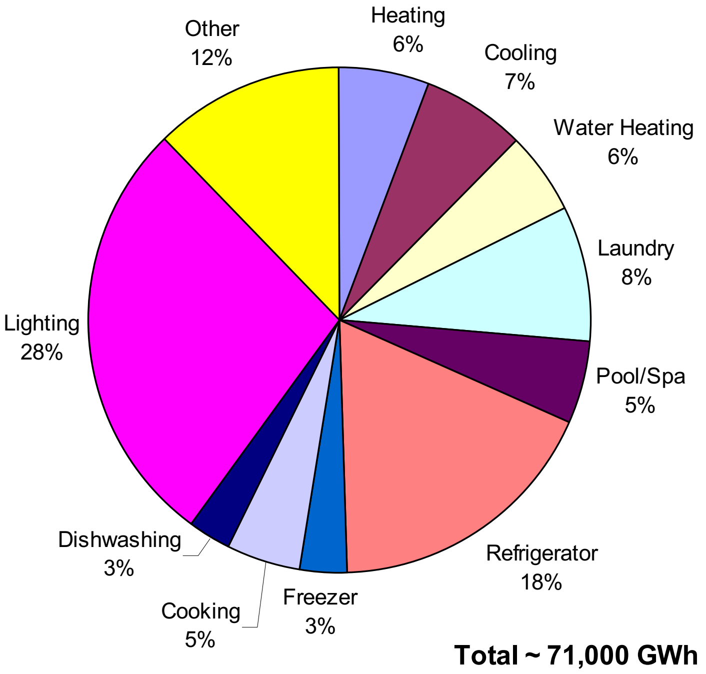
Figure 2-7
Residential Electricity Usage by Building Type within the Major IOU territories*



*Includes line losses. Source: CEC 2000. *California Energy Demand: 2000-2010*.

Residential energy consumption by end use is shown in Figure 2-8. Lighting is by far the largest end use, accounting for 28 percent of total consumption or about 20,000 GWh. Refrigerators are the next largest end use, accounting for about 18 percent of total consumption. Space heating and cooling together represent approximately 13 percent of total residential consumption.

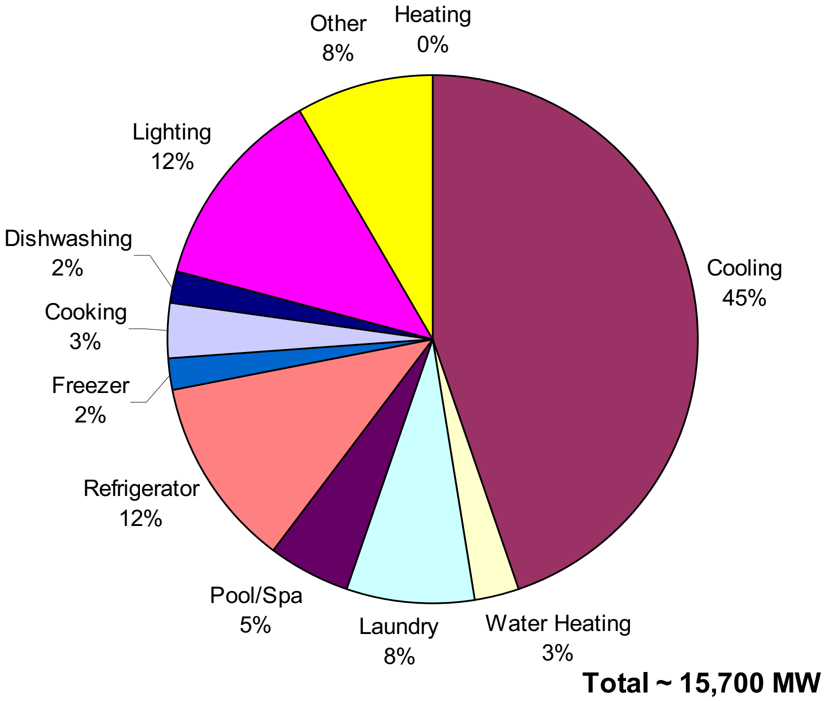
Figure 2-8
Residential Electric End-Use Breakdown for Major IOUs*



*Includes line losses. Source: CEC 2000. *California Energy Demand: 2000-2010 and XENERGY analysis.*

Peak demand is broken down by end use in Figure 2-9. Cooling clearly dominates residential peak demand, contributing 45 percent or roughly 7,000 MW, while lighting and refrigerators each account for 12 percent or just under 1,900 MW each. Water heating, cooking, dishwashing, freezer, and heating account for less than 5 percent each of peak demand in California.

Figure 2-9
Residential Peak Demand End-Use Breakdown for Major IOUs*



*Includes line losses. Source: CEC 2000. *California Energy Demand: 2000-2010 and XENERGY analysis.*

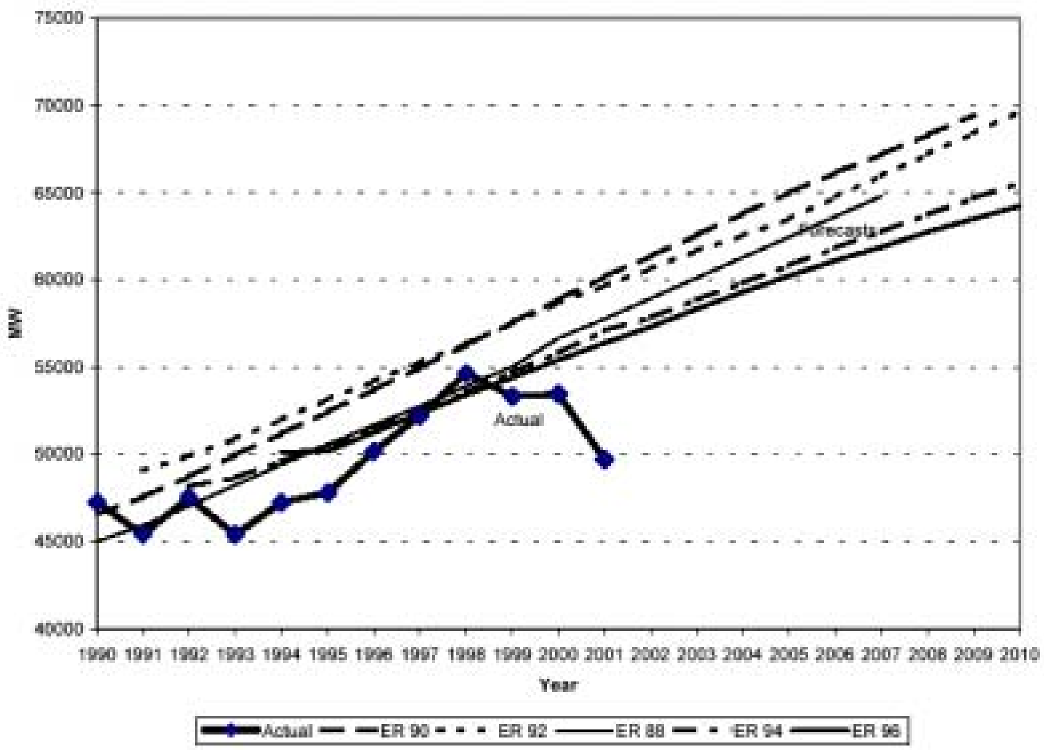
2.1.3 CEC Forecasts of Future Electric Consumption and Peak Demand

Historic Forecasts

To estimate energy-efficiency potential over time, it is necessary to benchmark savings to a forecast of electricity consumption. Fortunately, in California there is a consistent statewide process in place for electricity forecasting at the CEC, which has conducted such forecasts for many years. Throughout much of the 1980s and 1990s, these forecasts were produced as part of biannual Electricity Reports (ER).

Examples of forecasts produced for 1988 (ER88) through 1996 (ER96) are shown in Figure 2-10. Note that the historic forecasts assume normal weather and economic conditions. Actual consumption and peak demand in any given year can vary considerably in response to these conditions as seen in the unusual activity due to the energy crisis and resulting conservation behavior in 2001.

Figure 2-10
CEC Peak Demand Forecasts Versus Actual



Source: California Energy Commission (CEC) 2001a. *2002 – 2012 Electricity Outlook*. P700-01-004.

2001: An Extraordinary Year; 2002 Peak Demand Savings Ebb

On average, the CEC's forecasts have proven fairly accurate over time; however, like virtually all forecasts, the CEC's methods are not intended to predict extraordinary changes in usage associated with unexpected events like the energy crisis experienced in the second half of 2000 and most of 2001. As documented extensively elsewhere, energy consumption and peak demand decreased dramatically in 2001.[5]

Figure 2-11 illustrates the magnitude of the peak remand reductions achieved in 2001 and 2002. This reduction occurred as the result of a combination of voluntary demand response from consumers and installation of energy-efficient equipment, spurred both by the crisis itself and increased energy-efficiency program efforts.[6,7] The fraction of the reduction in 2001 attributable

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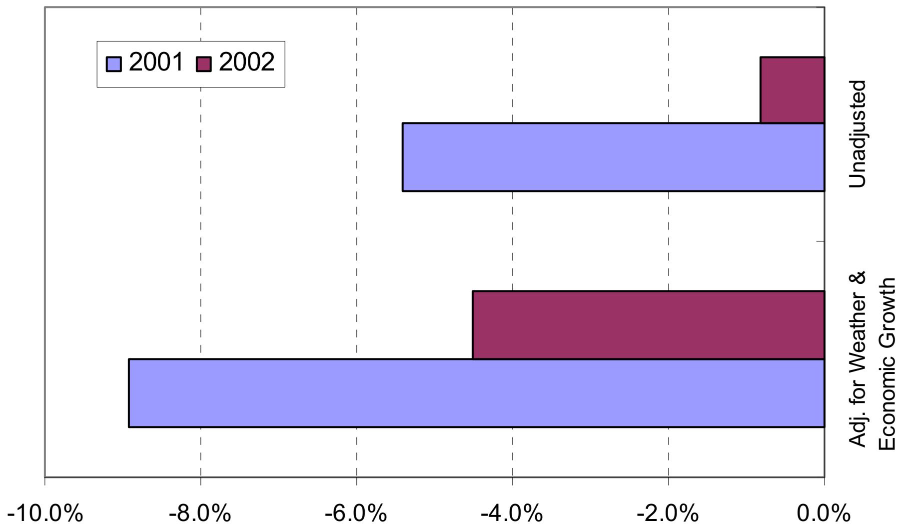
[5] For example, see Goldman, Eto and Barbose, "California Customer Load Reductions during the Electricity Crisis: Did They Help to Keep the Lights On?" Lawrence Berkeley National Lab, Report #49733.

[6] For an analysis of the 2001 Summer demand reduction, see *The Summer 2001 Conservation Report*, published by the California State and Consumer Services Agency, produced by the California Energy Commission under the direction of the Governor's Conservation Team, February 2002. See Also Lutzenheiser, Loren, *An Exploratory Analysis of Residential Electricity Conservation Survey and Billing Data: Southern California Edison,* prepared for the California Energy Commission, Summer 2001.

to voluntary conservation efforts versus installation of major energy-efficient equipment[8] is not currently known with certainty. However, it is likely that the majority of the reduction was due to voluntary conservation efforts. Goldman et al. (2002) estimate that roughly 70 percent of summer 2001 peak demand reduction was attributable to voluntary conservation efforts. However, there is evidence that there also was an extraordinary increase in consumer purchase of energy-efficient appliances and lighting due to heightened awareness of conservation and other external factors such as retailer exposure, utility upstream, and downstream rebate programs, as documented in statewide market share tracking studies.[9]

Figure 2-11
August 2001-2002 Peak Demand Reductions*



**Percent Change from Peak Demand for August 2000*
Source: California Energy Commission website, September, 2002. *Conservation Monthly*.

Peak demand through August 2002 has been consistently higher than 2001 levels but has remained below 2000 levels.[10] Figure 2-12 shows that the peak demand reductions in August 2002, when compared to 2000 levels, are approximately half of the reductions achieved in August 2001. The major IOUs report that the number of residential households participating in the 20/20 statewide conservation program remains are consistent with 2001 levels, but that these households are not saving as much as they did in 2001.

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[7] According to CEC 2001a, key factors driving both voluntary and hardware changes included demand reduction programs, electricity price increases, the 20/20 rebate program, winter rolling outages, and media exposure of the energy crisis and its potential costs to the State and consumers.

[8] Conservation refers here to behavioral changes in energy use, such as turning up thermostat settings during cooling periods; efficiency refers to permanent changes in equipment that result in increased energy service per unit of energy consumed, e.g., the installation of a more efficient air conditioner.

[9] *See RER. 2001b, California Residential Efficiency Market Share Tracking: Appliances 2001,* prepared for SCE.

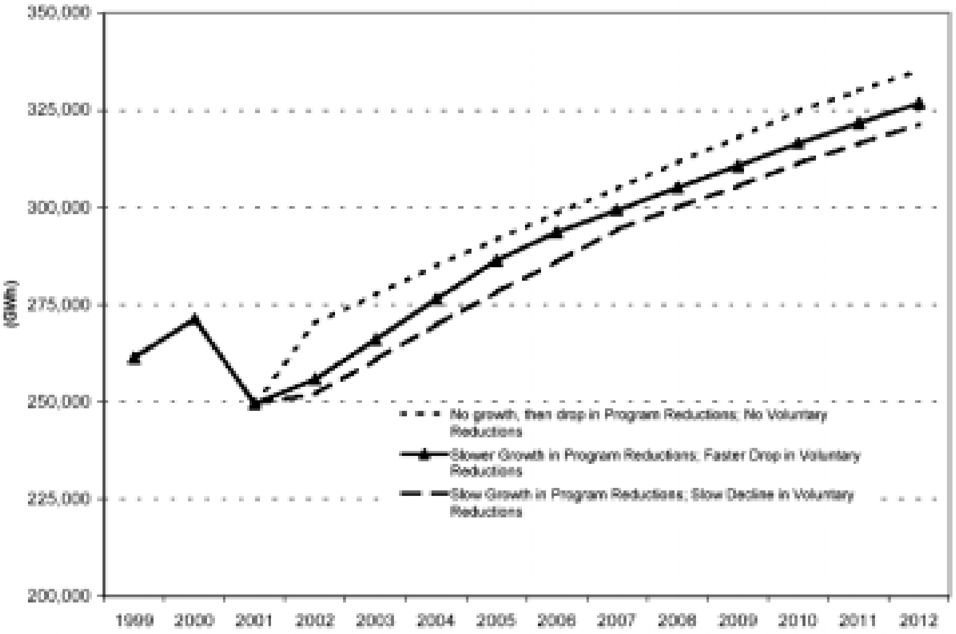
[10] Demand figures adjusted for economic growth and weather. California Energy Commission 2002: Conservation Monthly. www.energy.ca.gov.

Current Forecast Scenarios

The CEC developed several possible patterns of future trends in summer 2001 demand reductions. These patterns were based on alternative assumptions about the level and persistence of voluntary impacts and permanent, program impacts. (Note that program impacts, as used in the CEC's forecast scenarios, refer to the emergency program efforts initiated in response to the State's energy crisis, i.e., programs funded under SB 5X, AB 970, and AB 29X, not the public goods charge-based efficiency programs administered primarily by the State's major IOUs.) Refer to Appendix K for more information on programs offered to residential customers. The CEC developed three scenarios, one of which was selected as the most likely case, while the other two scenarios represent higher and lower cases. Figures 2-12 and 2-13 show these energy and peak demand forecast scenarios.

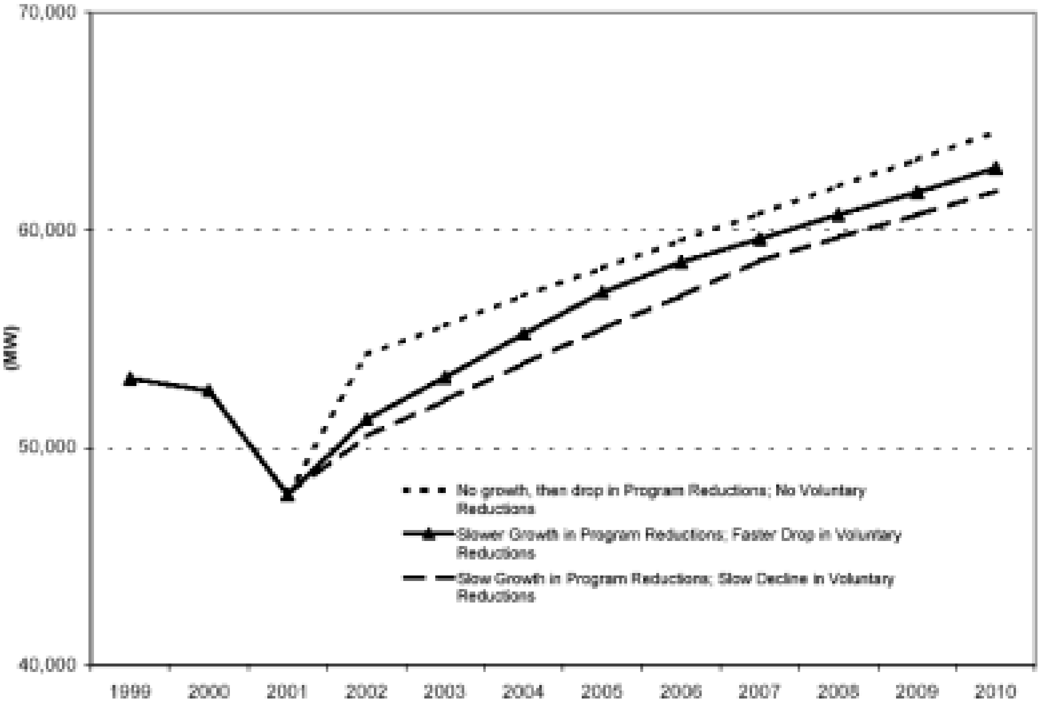
The electricity demand forecast scenario the CEC believes is the most likely scenario, is labeled "Slower Growth in Program Reductions; Faster Drop in Voluntary Reductions" and assumes that program impacts increase in 2002 but stay constant after that, while voluntary impacts decrease more rapidly. Under this scenario, 50 percent of the peak load reductions that occurred in 2001 persist for several years. The lower demand forecast scenario, labeled "Slow Growth in Program Reductions; Slow Decline in Voluntary Reductions," assumes that program impacts grow from 2001 to 2006 while impacts of voluntary reductions drop slowly over the period after an initial drop of 1,000 MW in 2002. Under the lower scenario, roughly 75 percent of 2001 reductions persist. The higher scenario, labeled, "No growth, then drop in Program Reductions; No Voluntary Reductions," assumes that there are no impacts from voluntary actions in 2002 and after, while impacts of programs stay constant until 2005 and then start declining. Under the higher scenario, only about 13 percent of the 2001 reductions persist.

Figure 2-12
CEC Energy Consumption Forecasts



Source: California Energy Commission (CEC) 2001a. *2002 – 2012 Electricity Outlook*. P700-01-004.

Figure 2-13
CEC Peak Demand Forecasts



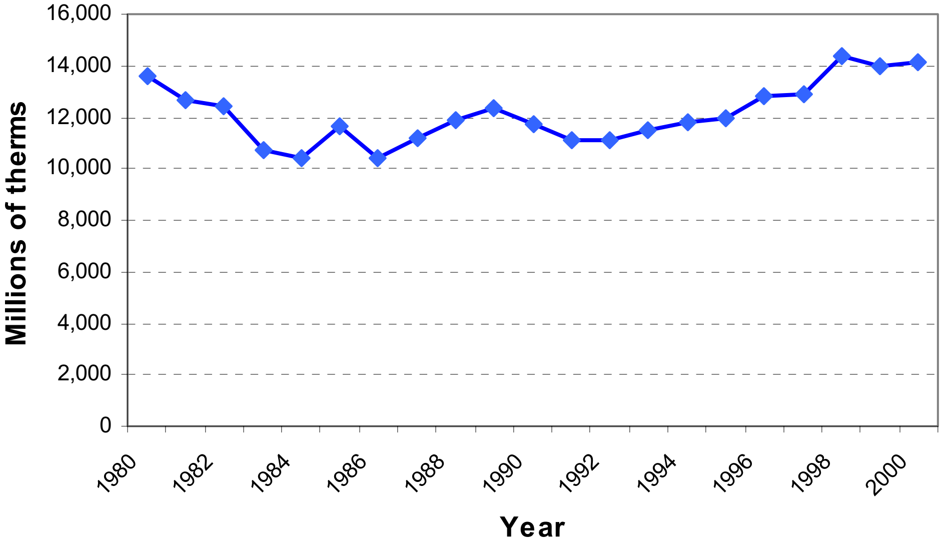
Source: California Energy Commission (CEC) 2001a. *2002 – 2012 Electricity Outlook*. P700-01-004.

2.2 NATURAL GAS USAGE

2.2.1 Overall Natural Gas Use and Past Trends

California is the second largest consumer of natural gas in the nation, second only to Texas. Figure 2-15 shows California natural gas consumption from 1980 through 2000. In the 1980s natural gas consumption statewide dropped by an average of 1.5 percent annually, followed by an average 2.5 percent increase annually in the 1990s. In 1998, the last year for which complete historic data was available, statewide consumption was 14,344 millions of therms (Mth).[11] Note that only partial data are available for 1999 and 2000; where possible we have used historical data through 2000 and have noticed cases where the values for 1999 and 2000 are forecast data.

Figure 2-14
California Natural Gas Consumption 1980 – 2000*



*Historic data through 1998. Source: CEC 2000. *California Energy Demand: 2000-2010.*

To understand and estimate the potential for further efficiency improvements in California's natural gas consumption, it is important to understand how natural gas is used in the State. Natural gas consumption in California has long been dominated by the residential and industrial, sectors, as shown in Figure 2-15. Figure 2-15 also shows that the percent of overall natural gas consumption represented by the residential and industrial sectors has shifted in recent years, while the percentage of the commercial sector and "other" category has remained relatively constant. From 1982 to 1994, residential gas consumption exceeded industrial consumption.

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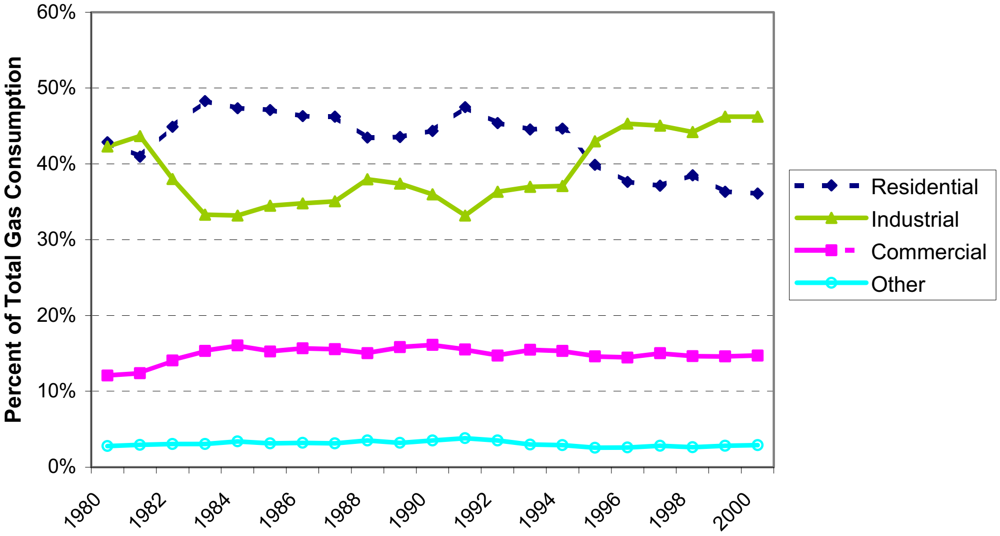
[11] CEC 2000. *California Energy Demand: 2000-2010 Staff Report. P200-00-002.*

Figure 2-15
Trends Natural Gas Consumption by Sector: 1980 – 2000*



*Historic data through 1998. Source: CEC 2000. *California Energy Demand: 2000-2010.*

However, since the early 1990s industrial consumption has steadily increased as residential consumption has decreased. The relative decline in gas use per household is due to the impacts of building standards on consumption and that there are few new gas appliances entering the market.[12]

Figure 2-16 shows the breakdown of consumption by sector in both 1980 and 2000. The comparison between years shows that the relative proportion of consumption by the industrial and commercial sectors increased while decreasing somewhat for the residential sector in the past 20 years. In 2000, the industrial sector represented the largest share of recent gas consumption, representing 46 percent of the State's usage, followed by the residential sector at 36 percent.

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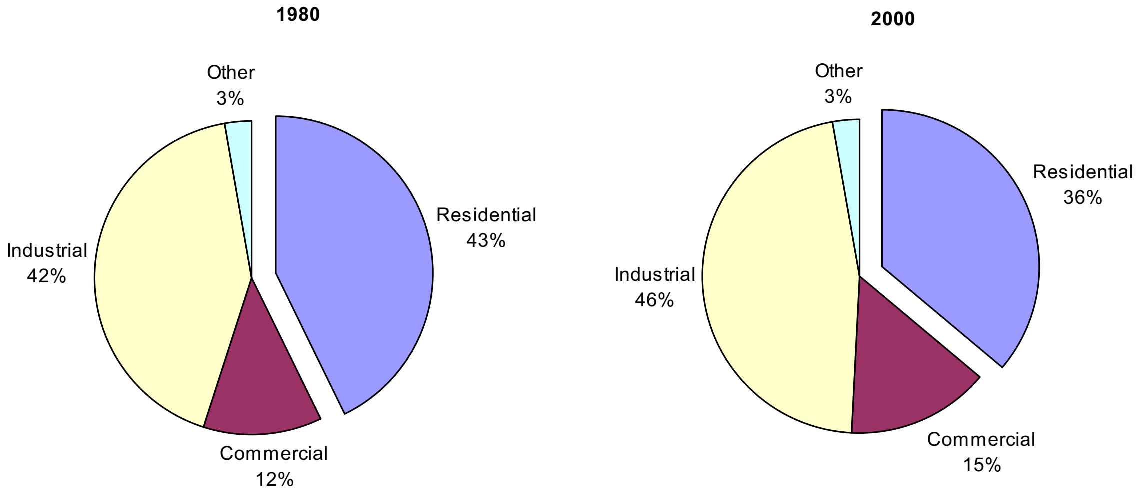
[12] CEC 2000. *California Energy Demand: 2000-2010 Staff Report. P200-00-002.*

Figure 2-16
Breakdown of California Energy Use by Sector in 1980 and 2000



Source: CEC 2000. *California Energy Demand: 2000-2010.*

2.2.2 Residential Sector Natural Gas Use for the Major IOUs

The scope of this study includes residential natural gas consumption in the territories of the State's three major gas IOUs, PG&E, SCG, and SDG&E. In the areas of the state where natural gas service is available, the gas IOUs account for 99 percent of the State's total natural gas consumption, with the remaining 1 percent accounted for by municipal utilities. Therefore, this report uses statewide figures for gas.

As discussed above, in 2000 the residential sector was second-largest contributor to the State's natural gas consumption. Residential customers within the service territories of the major IOUs accounted for approximately 5,000 Mth in 2000, which represented about 36 percent of the total gas consumption in the State, which was estimated to be over 14,000 Mth in 2000.[13]

Natural gas consumption within the residential sector can be analyzed in a variety of ways. In figure 2-17, we summarize the characteristics of residential natural gas consumption by building type. Single-family homes represent approximately 75 percent of the sector's consumption, followed by multi-family homes at about 20 percent.

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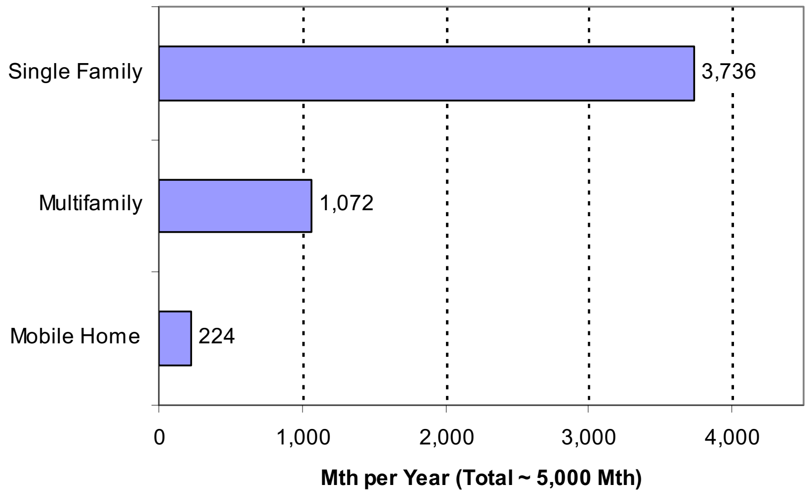
[13] ibid.

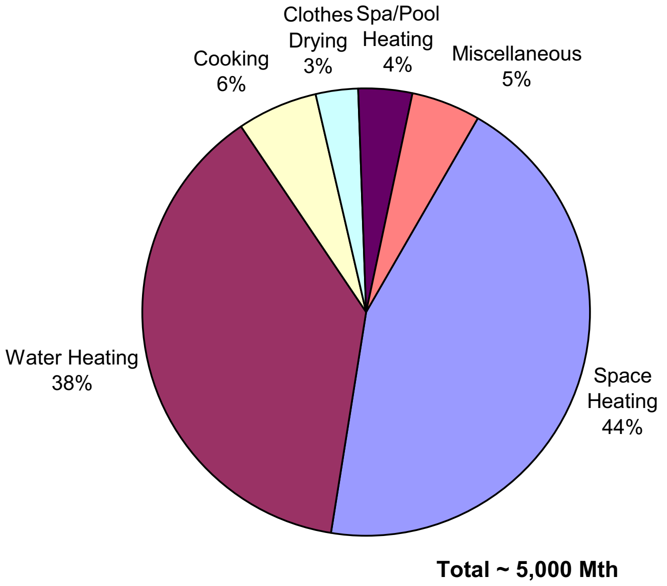
Figure 2-17
Residential Natural Gas Consumption by Building Type



Source: CEC 2000. *California Energy Demand: 2000-2010.*

In the residential sector, gas is used for a variety of purposes, including space heating, water heating, clothes drying, cooking, and pool and spa heating. Figure 2-18 illustrates that space and water heating are by far the dominant end uses at 44 percent and 38 percent, respectively.

Figure 2-18
Breakdown of Residential Gas Consumption by End Use

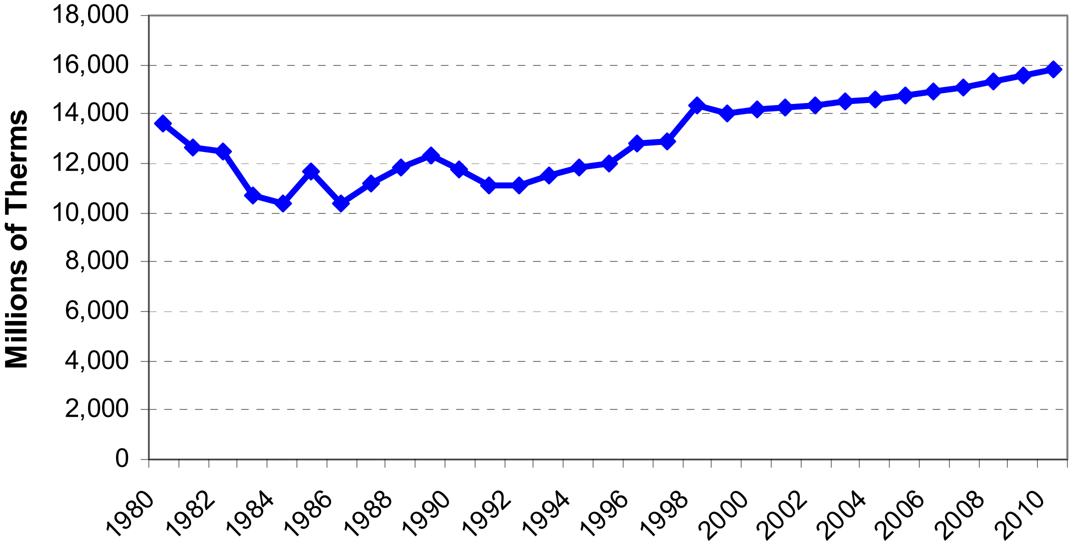


Source: CEC 2000. *California Energy Demand: 2000-2010.*

2.2.3 CEC Forecasts of Future Natural Gas Consumption

To estimate energy-efficiency potential over time, it is necessary to benchmark savings to a forecast of natural gas consumption. In California there is a consistent statewide process in place for energy forecasting at the CEC.[14] Figure 2-22 shows the CEC's forecasted gas consumption statewide through 2010. Statewide natural gas consumption in 1998 was 14,344 Mth and is the last year for which complete historical data was available. From 1998 to 2004, consumption is forecasted to grow at a rate of 0.3 percent annually through 2004. The growth rate is expected to increase from 2005 to 2010 to reach 15,802 Mth. This represents an average increase of 0.8 percent annually from 1998 to 2010.

Figure 2-19
CEC Gas Consumption Forecast through 2010*



*Historic data through 1998. Source: CEC 2000. *California Energy Demand: 2000-2010.*

The following sections provide additional context for this study. Section 3 provides information on past and current energy-efficiency programs, Section 4 discusses the methodology, and Section 4 presents the scenarios used for this study.

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[14] The historic forecasts assume normal weather and economic conditions. Actual consumption in any given year can vary considerably in response to these to conditions.

3

ENERGY EFFICIENCY PROGRAMS

This section presents information on California's energy-efficiency programs in order to provide additional context on current efforts to increase energy efficiency. We discuss both electric and gas programs, but focus on electric energy efficiency. In addition, we provide historic information on all programs but concentrate on the residential sector programs of the major IOUs. As with the information presented in Section 2 of this report, information on past efficiency programs provides an important context for the estimates of energy-efficiency potential developed for this study.[1]

Energy use in California and the rest of the U.S. is a function of many factors. Generally, energy use increases during times of increased economic activity and population growth and decreases or remains flat during periods of weak economic activity or net decreases in population growth. Energy use changes as a result of another key factor: efficiency. Efficiency measures the amount of work or useful services that are obtained from a unit of energy consumed. The more efficient an energy-using system, the more work or useful service, such as light or heat, that is obtained per unit of energy consumed. Note that efficiency is not the same as conservation. Conservation involves using less of a resource, usually through behavioral changes, such as raising a thermostat setting from 75 to 78 ^{o}F for air conditioning on a hot day. As a result of the availability of gains from efficiency and conservation, the relationship between economic growth and electricity use is far from constant.

3.1 CALIFORNIA ENERGY-EFFICIENCY PROGRAM IMPACTS

California has long been both a national and international leader in developing programs and policies aimed at increasing the efficiency with which energy is used in the State's economy. Savings from the State's appliance and building standards occur every year directly as a function of construction of new buildings and purchases of new appliances covered by the standards. Because standards require minimum efficiency levels, these savings are immediate and permanent and tend to follow building construction activity levels. Spending on programs, however, has increased and decreased, sometimes dramatically, over time. Savings from efficiency programs, run primarily by utilities, vary over time as a function of program expenditure levels. Some of the key milestones and trends in the 25-year history of efficiency programs in the State include the following:

- In the mid-1970s, the State, through the California Energy Commission (CEC), developed comprehensive energy codes to require that new residential and commercial

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[1] In this section and throughout the report, we focus on first-year energy savings attributable to measures and programs for several reasons. First, most resource planners are interested in first-year savings because this is the amount of energy that offsets the requirement for additional generation resources. Second (and especially for this section), first-year savings are the most widely published and accessible figures available. Third, given typical measure lives of 10 years or more, first-year savings provide a relatively good approximation for annual savings over the short- to middle-term focus of this study.

buildings and appliances meet minimum energy-efficiency standards. The CEC subsequently worked on 3-year cycles to continuously review and upgrade building standards. In 2001, the CEC adopted a set of emergency standards in response to the energy crisis.

- In the late 1970s and 1980s, energy regulators and utilities developed and implemented the first utility-based energy savings programs for the State's major IOUs. These programs focused on squeezing out unnecessary energy waste and installing first-generation efficient equipment. Spending on these programs grew rapidly in the early 1980s but then plummeted in the late 1980s as wholesale energy prices decreased.
- In the early 1990s, a group of government, utility, and public interest groups worked together to develop a process for reinvigorating investment in energy efficiency. The California Collaborative, as the group was known, developed an incentive mechanism that rewarded utilities for effective investments in energy-efficiency programs. The work of the Collaborative led to a new surge in efficiency investments that lasted until 1996, when the process of electric restructuring led to another dramatic drop in efficiency program spending.
- In the late 1990s, recognizing their long-term value to the State, California held programs and funding in place during restructuring, at a time when other states completely eliminated programs and funding. Nonetheless, programs in the late 1990s faced several challenges: funding levels were lower than during the earlier part of the decade, policy objectives shifted from resource acquisition to market transformation, and the nexus of program oversight shifted temporarily to the California Board for Energy Efficiency.

Efficiency of California Electricity Use Compared to Rest of U.S.

Partly as a result of the State's assertive energy programs and policies, California is the nation's most efficient state in terms of per capita electricity consumption.[2] As shown in Figure 3-1, since 1974 electricity use per person in the U.S. has grown at an annual rate of 1.7 percent. Over the same time period, however, per capita electricity use in California has remained almost constant, growing at only 0.1 percent per year, while per capita use in the rest of the western U.S. grew at 1.2 percent. For example, had California's per capita electricity use increased at the same rate as did the rest of the country's over the last quarter century, peak demand in the State would have been 15,000 MW higher than it was in 2000. This would have required the construction and siting of roughly 30 additional major power plants throughout the State.

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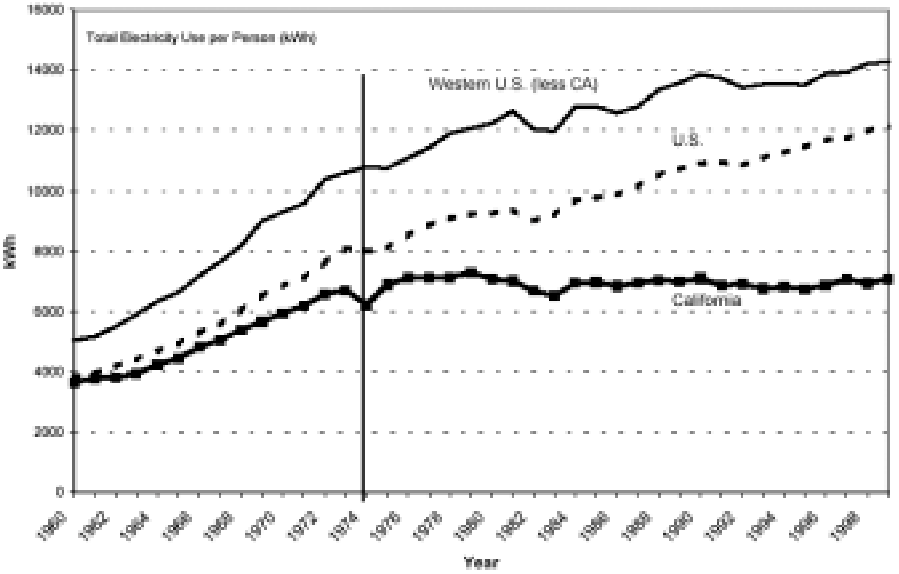
[2] Factors such as weather and the types of industries located in California can also contribute to lower per capita energy use.

Figure 3-1
Electricity Consumption per Capita: 1960 - 2000

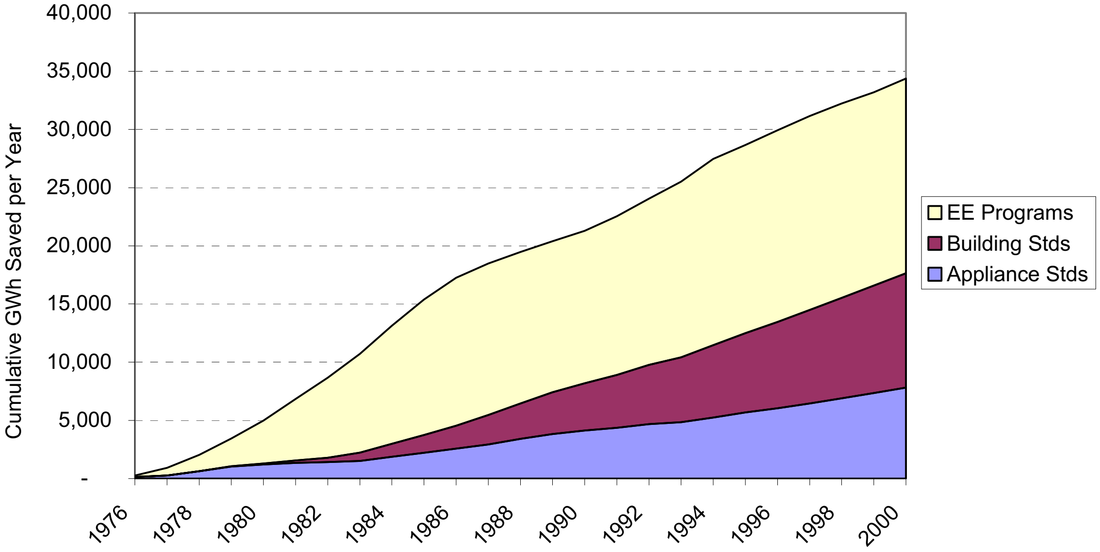


Source: California Energy Commission (CEC) 2001a. *2002 – 2012 Electricity Outlook*. P700-01-004.

3.1.2 Electric Savings from Energy-Efficiency Programs

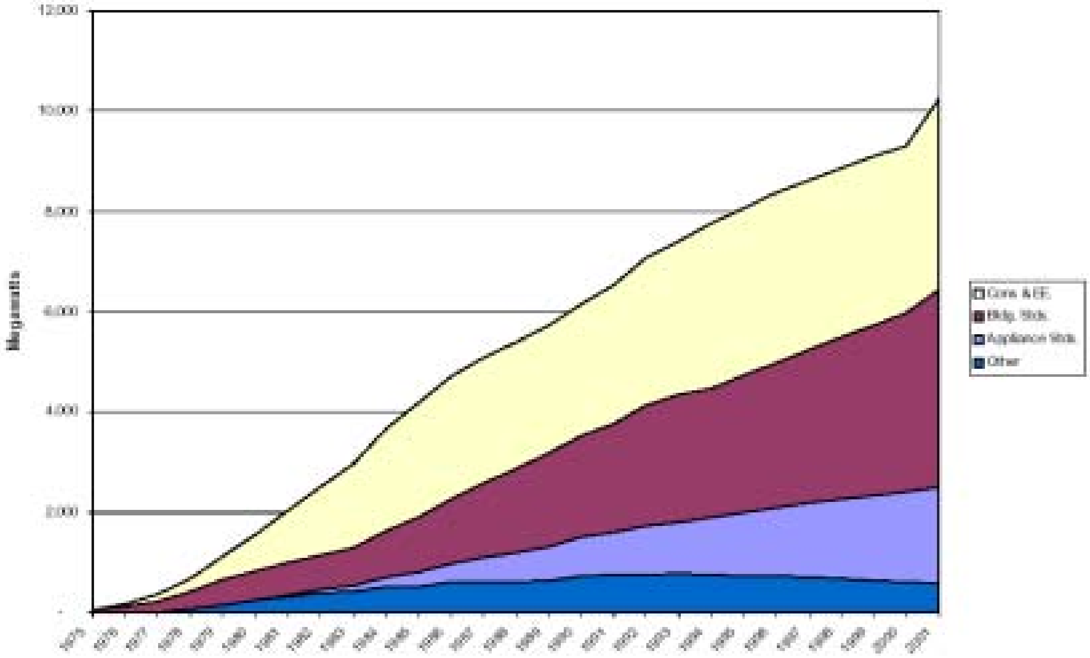
As shown in Figures 3-2 and 3-3, cumulative energy and peak demand savings from programs and standards were about 34,000 GWh per year and 9,000 MW, respectively, through 2000. Savings from energy-efficiency programs accounted for roughly half of the impacts.

Figure 3-2
Electric Savings Impacts of Energy-Efficiency Programs and Standards



Source: Historic data compiled by CEC staff. Smith 2002.

Figure 3-3
Peak Demand Impacts of Energy-Efficiency Programs and Standards



Source: California State and Consumer Services Agency, 2002.

Electric savings from energy-efficiency programs have varied widely throughout the past 25 years as a function of changes in annual funding levels. Figure 3-4 shows that spending levels have peaked twice, once in 1984 and then in 1994, while expenditure downturns and valleys occurred in the latter half of both the 1980s and the 1990s. These dramatic funding swings have reflected changes in policy makers' perceptions about energy prices and the need for new power plants, as well as philosophical shifts in the State's political and regulatory climate and goals, such as the shift from resource acquisition strategies in the mid-1990s to market-transformation strategies of the late-1990s. Expenditures increased in 2000 primarily because of the use of carryover funds that were not expended in previous years and a surge in program demand driven by the increase in wholesale and retail[3] electricity prices that occurred in the second half of the year.

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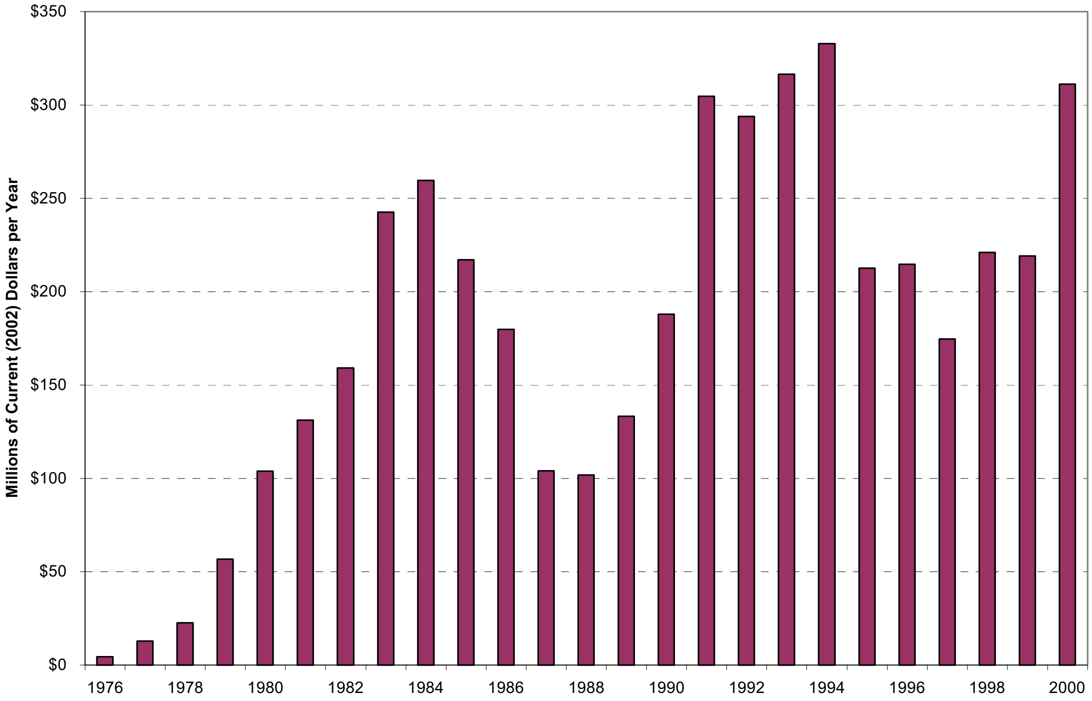
[3] Only customers in the SDG&E service territory were exposed to increased electric prices in the summer of 2000.

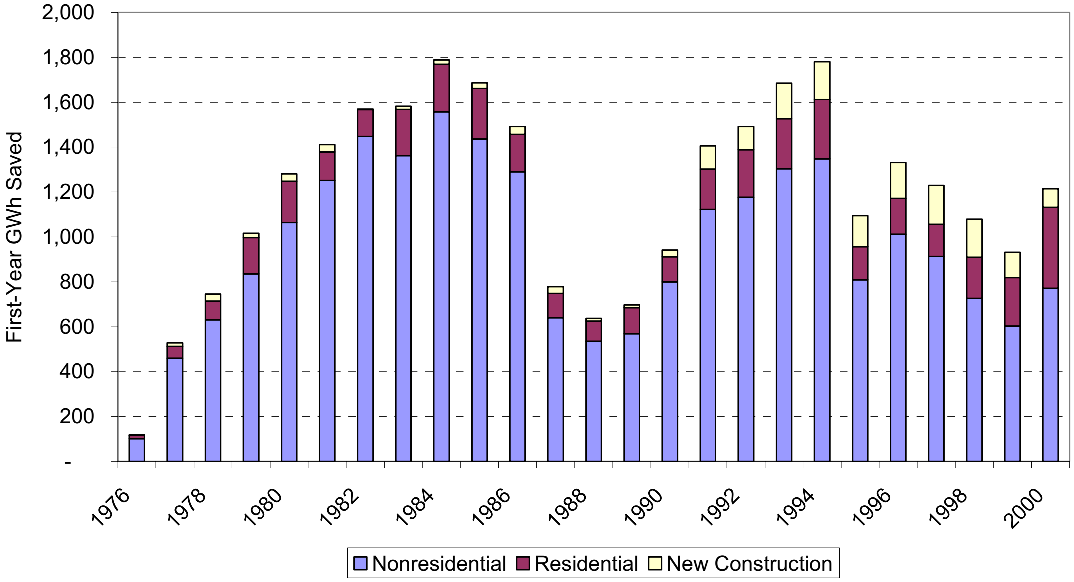
Figure 3-4
Annual Electric Energy-Efficiency Program Expenditures for Major IOUs (in current dollars)



Source: Historic data compiled by CEC staff. Smith 2002.

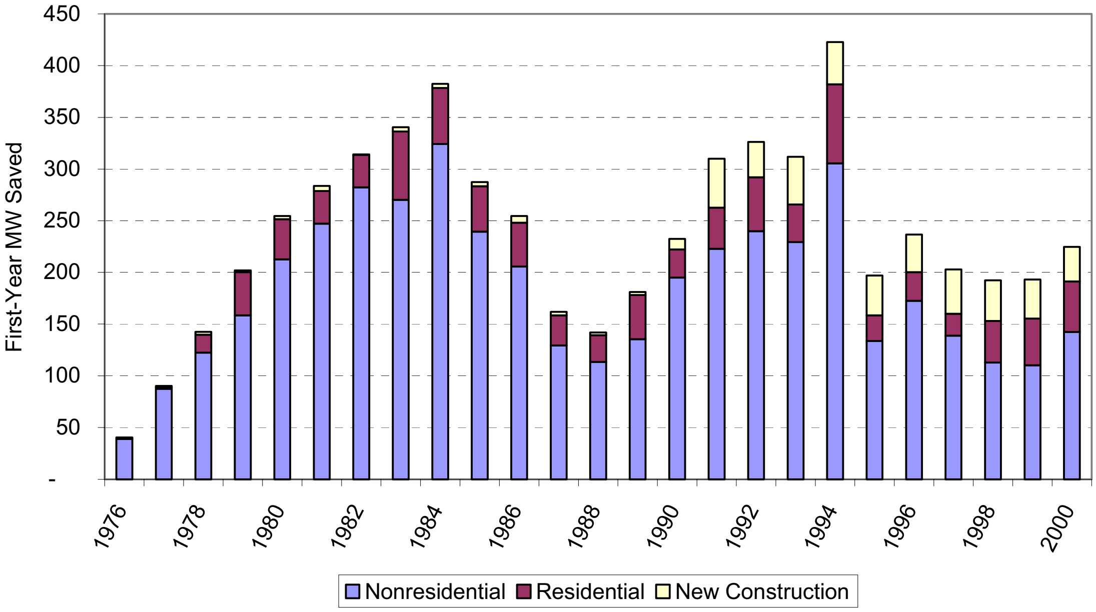
Annual program impacts for major IOU electric efficiency programs are shown in Figures 3-5 and 3-6. The pattern of energy savings over time generally follows expenditure levels. First-year energy savings of 1,800 GWh have been achieved during spending peaks, but first-year savings have tended to average around 1,000 GWh. Peak demand savings have averaged around 200 MW but reached a high of over 400 MW of savings in 1994. Nonresidential program savings have dominated for both energy and peak demand, with an average of 80 percent, but represented closer to 70 percent of savings in recent years.

Figure 3-5
First-Year Electric Energy Savings for Major IOUs' Efficiency Programs



* New Construction category includes all sectors
Source: California Energy Commission (CEC) 2000. *California Energy Demand: 2000-2010*.

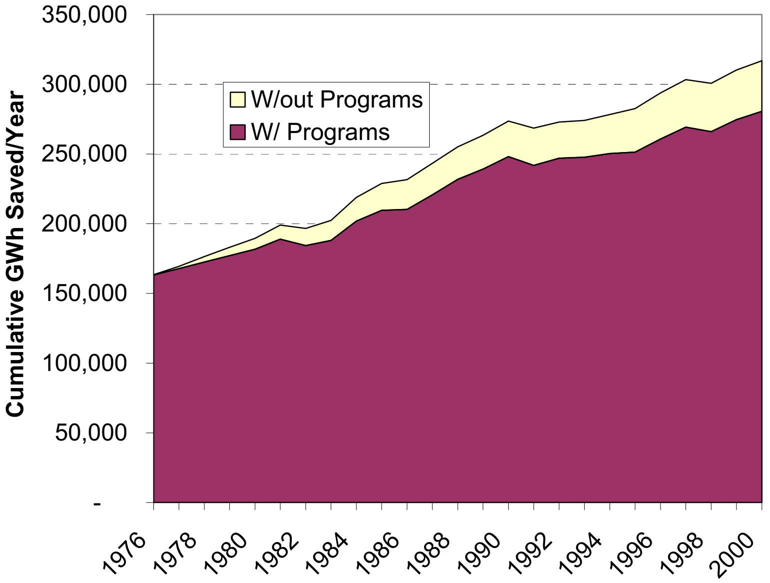
Figure 3-6
First-Year Peak Demand Savings for Major IOUs' Efficiency Programs



* New Construction category includes all sectors
Source: California Energy Commission (CEC) 2000. *California Energy Demand: 2000-2010*.

The cumulative effect of California's efficiency programs and standards is shown in relation to actual energy consumption over the past 25 years in Figure 3-7. According to CEC estimates, these programs and policies have resulted in savings of 9,000 MW.

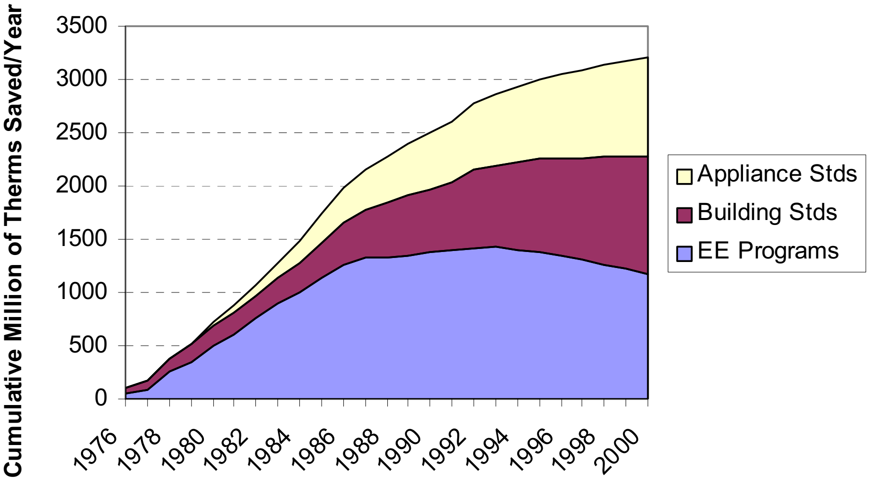
Figure 3-7
Cumulative Impact of California Electric Efficiency Programs



3.1.3 Natural Gas Savings from Energy Efficiency Programs

As shown in Figure 3-8, cumulative natural gas savings from programs and standards were approximately 2,000 millions of therms (Mth) per year through the year 2000. Savings from energy-efficiency programs accounted for roughly half of the impacts overall.

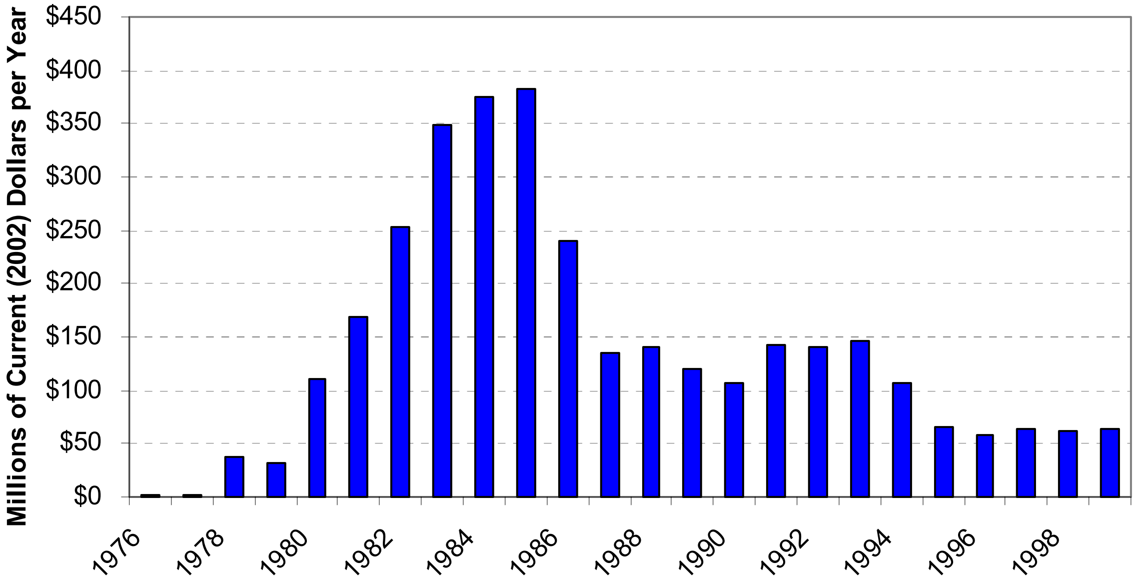
Figure 3-8
Cumulative Natural Gas Savings Impacts of Energy-Efficiency Programs and Standards



Source: California Energy Commission (CEC) 2000. *California Energy Demand: 2000-2010.*

Figure 3-9 shows that spending levels for natural gas programs peaked in 1985, while expenditure downturns occurred in the latter half of both the 1980s and the 1990s. In recent years, funding levels remained relatively constant, averaging roughly $75 million annually from 1995 through 1999.

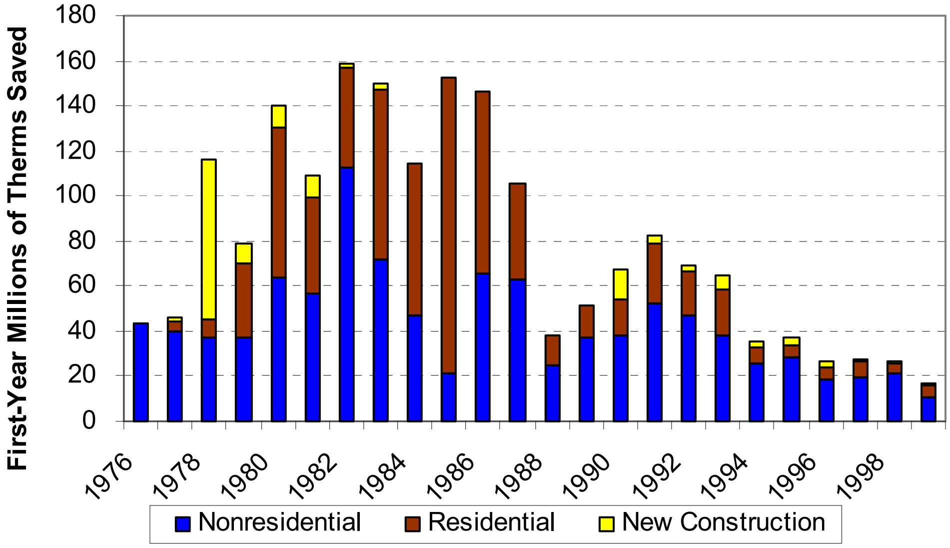
Figure 3-9
Annual Natural Gas Energy-Efficiency Program Expenditures for Major IOUs
(in current dollars)



Source: Historic data compiled by CEC staff. Smith 2002.

Annual program impacts for major IOU natural gas efficiency programs are shown in Figure 3-10. The pattern of energy savings over time generally follows expenditure levels. Tightening of building and appliance standards as well as technical constraints on increased gas efficiency have also dampened program impacts in recent years. First-year energy savings of 151.5 Mth were achieved during a spending peak in 1985, with first-year savings averaging around 79 Mth. In recent years, the nonresidential sector has accounted for the majority of natural gas savings achieved, followed by savings in the residential sector. Residential program savings accounted for on average 35 percent of natural gas savings historically.

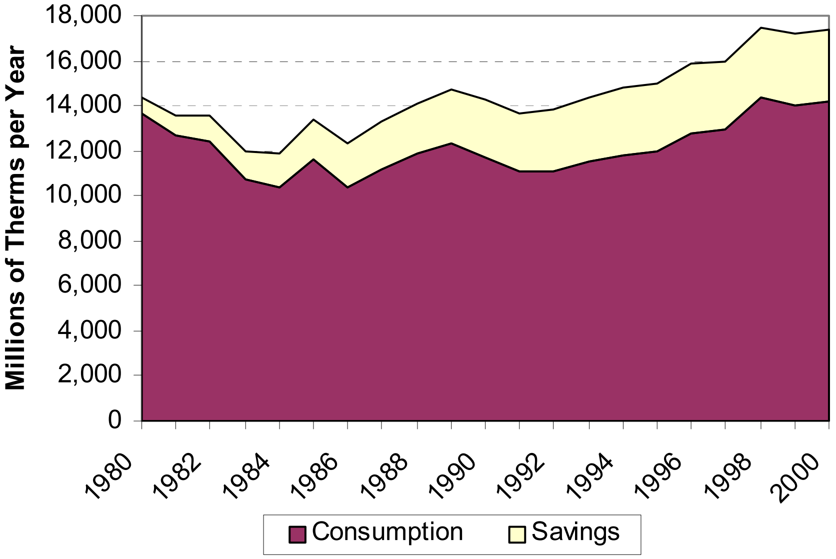
Figure 3-10
First-Year Natural Gas Savings for Major IOUs' Efficiency Programs



Source: Historic data compiled by CEC staff. Smith 2002.

Figure 3-11 presents the cumulative effect of California's efficiency programs and standards in relation to natural gas consumption over the past 25 years. Savings as a proportion of consumption has remained fairly constant over time.

Figure 3-11
Cumulative Impact of California Natural Gas Efficiency Programs and Standards



Source: California Energy Commission (CEC) 2000. *California Energy Demand: 2000-2010.*

3.2 MAJOR IOUS' RESIDENTIAL PROGRAM IMPACTS: 1990 - 2000

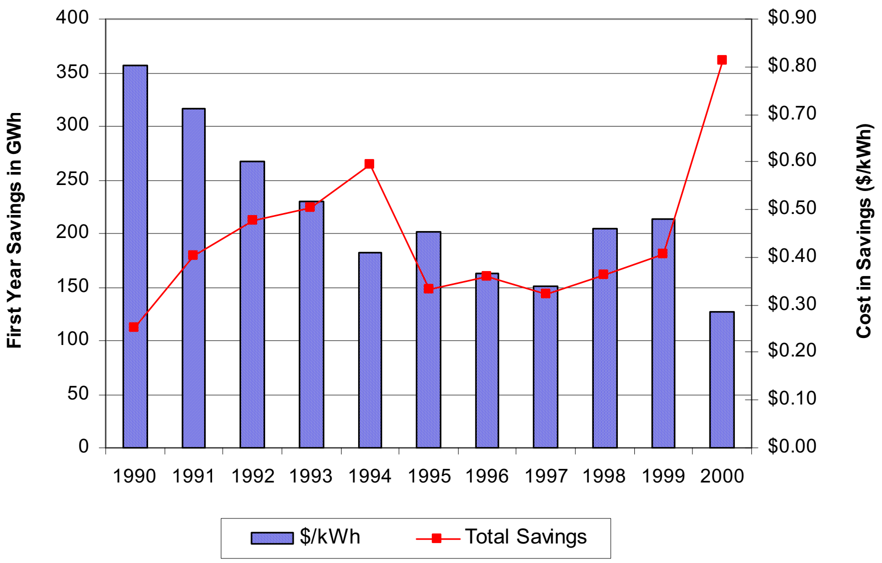
Because the focus of this report is on energy-efficiency potential in the residential sector of the major IOUs, in this subsection we present summary data on the impacts of the major IOUs' residential energy-efficiency programs over the period 1990 to 2000.

3.2.1 Residential (Existing Construction) Electric IOU Program Impacts

Figure 3-12 shows the combined long-term electric energy-efficiency program activity among the major IOUs from 1990 through 2000. The graph presents the total net kWh savings[4] as well as the administrative expenditures per unit of savings.

First-year savings increased steadily from 1990 to 1994, remained relatively constant from 1995 through 1999 and then almost doubled in 2000. The average program cost[5] per unit of savings declined steadily from 1990 to 1994 even as total savings rose and has fluctuated since, peaking in 1999. Note, however, that regulatory reporting requirements were changing in the late 1990s as the California Board for Energy Efficiency (CBEE) began requiring new reporting formats. In addition, many programs were changed in response to orders from the CBEE and California Public Utilities Commission (CPUC) to shift programs away from resource acquisition and toward market transformation strategies.

Figure 3-12
Residential Electric Utility Energy-Efficiency Savings and Expenditures* (current dollars)



*Includes low income programs.

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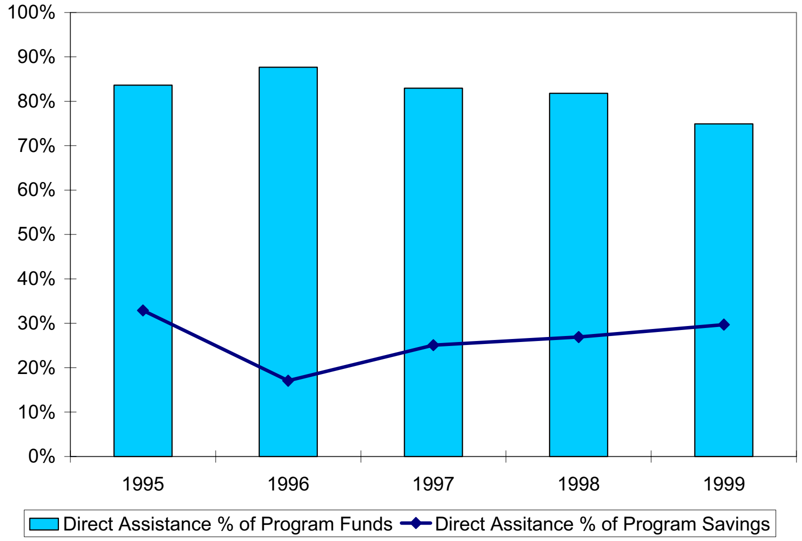
[4] Gross program savings reflect all impacts attributable to measures installed using program funding, while net savings factor out impacts that would have occurred anyway, even without program funding, due to naturally occurring customer investment in energy efficiency.

[5] Note that "program" costs include all utility expenditures on the programs including incentives for purchasing efficient equipment paid out to customers. Program costs do not include the additional costs to program participants of purchasing the energy-efficient equipment that are not covered by incentives.

As it turns out, the majority of expenditures were associated with direct assistance programs that serve low-income customers, as shown in Figure 3-13 for 1995 through 1999. The figure also shows that although direct assistance programs accounted for roughly 80 percent of residential natural gas program expenditures, they only make up roughly 30 percent of program impacts.

Figure 3-13
Direct Assistance Program as Percent of All Natural Gas Program Expenditures and Impacts, 1995 – 1999*



*Source: California Energy Commission IOU efficiency program tracking spreadsheet.

3.2.2 Residential (Existing Construction) Natural Gas IOU Program Impacts

Figure 3-14 illustrates the natural gas energy-efficiency residential program activity among the major IOUs for all sectors over the period 1990 to 1999. In recent years, the residential sector has represented about 35 percent of the savings achieved each year. In general, the statewide trend from 1990 through 1994 for gas savings through energy-efficiency programs was toward decreasing annual savings, peaking at 26.6 Mth in 1991. Following 1994, savings held steady, until 1999. However, savings decreased much more rapidly than the funding levels decreased, leading to increased program costs per unit of savings.

The average program cost per unit of savings climbed rapidly from 1993 to 1994, after remaining steady since 1990. From 1995 to 1997, again program cost per unit savings remained steady with a drastic spike in 1998.[6] In 1998, many programs were changed in response to orders from the CBEE and CPUC to shift programs away from resource acquisition and toward market transformation strategies. While more funds were available for efficiency programs in the years following this change, annual natural gas savings continued to decline slowly. This decline

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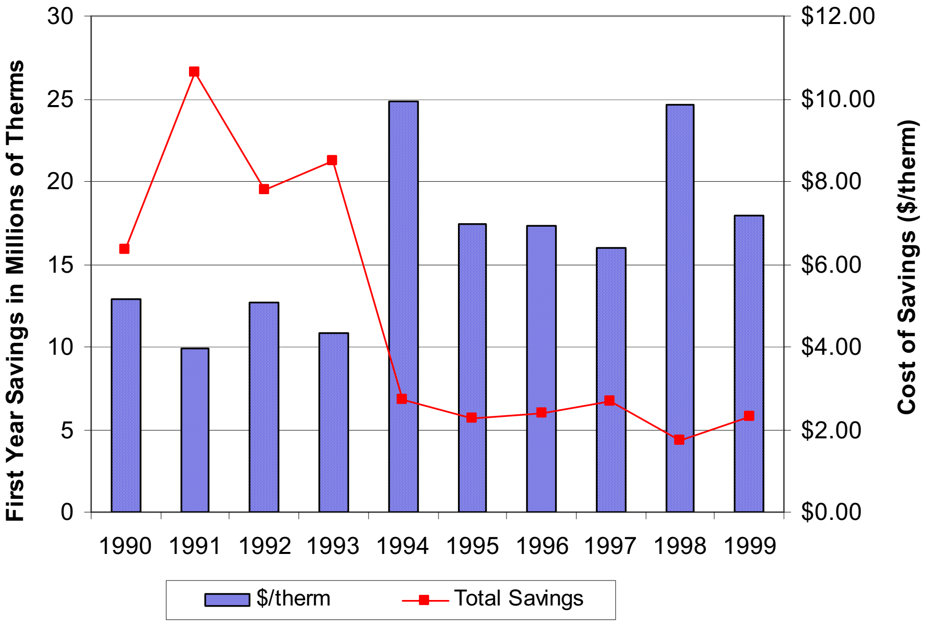
[6] Note that "program" costs include all utility expenditures on the programs including incentives for purchasing efficient equipment paid out to customers. Program costs do not include the additional costs to program participants of purchasing the energy-efficient equipment that are not covered by incentives.

reflects the effects of increased building and appliance standards as well as technical constraints on increased gas efficiency.

Figure 3-14
Natural Gas Energy-Efficiency Savings and Expenditures*(in Current Dollars)



*Includes low income programs.

Source: California Energy Commission (CEC) 2000. *California Energy Demand: 2000-2010*. P200-00-002. Historic data compiled by CEC staff. Smith 2002.

3.3 SUMMARY OF RECENT (PY2002) IOU PROGRAMS

This subsection briefly summarizes recent residential program activities administered by the major IOUs in 2002.[7] In 2001, the residential energy-efficiency programs administered by the California IOUs underwent a fairly dramatic shift in focus. Specifically, program designs began moving away from the longer-term goals of market transformation toward the goal of shorter-term energy savings, especially among hard-to-reach customer segments. Some of the efforts to coordinate programs statewide (e.g., consistent incentive levels, coordinated implementation efforts) were diminished as utility-specific efforts were introduced to more rapidly achieve summer 2001 demand reductions. To some extent, this shift in emphasis continues in PY2002 although a considerable portion of the overall residential program funding has been allocated to statewide, coordinated efforts.

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[7] This energy-efficiency program information focuses on statewide programs and was developed through a review of utility filings, quarterly reports, and program manager interviews. There were also numerous smaller local programs, such as those funded through SBx1-5 for the PY2002 program year. We do not discuss these here for two reasons: first, that these programs were started late in the year; and second, the funding and savings information available was not sufficient for us to provide the necessary detail in this section and in Appendix K. For more information on the various funding sources available, see for example, Goldman, Eto, and Barbose, 2002.

3.3.1 Residential Retrofit Programs

Lighting and Appliances Incentive Programs

Beginning in PY1999, the utilities offered a coordinated, statewide program to promote the purchase of residential energy-efficient lighting technologies and appliances. While financial incentives were available through this program, the focus of program activity during PY1999-2000 was on upstream, market transformation-oriented activities (e.g., retail stocking and merchandising, salesperson training, etc.). However, beginning in PY2001, the emphasis was shifted more towards downstream rebates, and a number of utility-specific efforts were introduced to accelerate program accomplishments and address the state's short-term need to more quickly reduce electricity demand. Supplemental funding for some of these efforts was provided in PY2001 through SBx1-5.

With nearly $50 million allocated toward the upstream and downstream components of this program during PY2000-2001, only the upstream lighting program elements are funded in PY2002 (approximately $9 million budgeted). However, the PY2002 budgets for downstream lighting and appliance rebates have been incorporated into the statewide Residential Single-family and Multifamily Programs (see below).

Appliance Recycling Program

The utilities have allocated approximately $7 million toward the Statewide Appliance Recycling Program during PY2002. The CPUC appointed Southern California Edison (SCE) as the sole administrator for this program, in which customers can receive either a cash incentive or a package of compact fluorescent light bulbs (CFLs) in exchange for recycling a refrigerator or freezer. In PY2001, the utilities spent about $16 million on similar, separately administered efforts. In PY2000, SCE was the only utility to offer an appliance-recycling program, spending approximately $7 million on the effort.

Comprehensive Retrofit Programs

The majority of program funding for comprehensive retrofit measures has been allocated in PY2002 to the Statewide Residential Single-family and Multifamily Programs. The programs include consumer incentives for various retrofit measures (e.g., appliances, lighting, HVAC, etc.), education and information, contractor training and participation, and home energy surveys. With over $31 million budgeted, this represents the most significant component of the overall residential energy-efficiency program portfolio for PY2002.

This statewide program draws together a number of previously administered programs, including the Residential Contractor Program and the Residential Energy Management and Services Program. While offered separately in PY2000 and PY2001, these programs historically accounted for the majority of utility funding in the comprehensive retrofit program area. For example, the statewide Residential Contractor Program maintained budgets of over $20 million in PY2000 and PY2001. However, this program was aimed at promoting a self-sustaining contractor market for energy-efficiency services, whereas the current statewide effort—while engaging contractors in the participation process—has more of an end-use customer focus. At least one utility (PG&E) has formally maintained the contractor-training element of this program in PY2002 through the Comprehensive Whole-House Residential Retrofit Program, although the budget allocated for this function is significantly lower than in prior years.

Hard-to-Reach Programs

In PY2002, the utilities placed considerable emphasis on delivering programs that were specifically designed to target hard-to-reach segments, particularly the working poor or non-English-speaking customers. Together, these efforts accounted for over $10 million in residential program funding. These programs provided a combination of activities, including customer information and education materials, home energy audits, and no-cost installation of energy-efficiency measures. A considerable number of these programs in PY2002 were targeted at mobile homes and multifamily housing.

3.3.2 New Construction Programs

In PY2002, approximately $14 million has been allocated to the statewide California ENERGY STAR® New Homes Program, which has been designed to standardize a number of the different utility-specific programs offered in prior years. Generally, the effort in PY2002 offers different incentive levels in order to encourage the exceeding of Title 24 standards in single- and multi-family new home construction by 15 to 20 percent.

During PY2000-2001, the utilities offered a variety of separately administered programs targeting the residential new home market. These efforts are described briefly below:

- **PG&E** – A considerable effort was made to raise awareness and promote energy efficient new home construction during PY2000-2001 via PG&E's Targeted Consumer Promotion and Awareness Program. PG&E spent over $4 million annually providing information to potential new homebuyers via TV advertising, direct mail, newspaper inserts, utility bill inserts, and web site advertising. In addition, PG&E's Integrated New Home Products Program promoted ENERGY STAR new homes to builders and consumers. The program developed new builder trade sheets, consumer brochures, and trade advertisements, and held builder-training sessions.

- **SCE** – During PY2000-2001, SCE offered a variety of information materials and incentives via the Residential New Construction Program. With annual budgets near $3 million, this program provided incentives to manufacturers to reduce the first cost of high-efficiency central air conditioners; incentives to contractors to complete installation before the summer months; incentives to builders for properly sizing their air-conditioning units; a Builders Resource Guide on energy efficiency; and informational seminars for residential customers.

- **SDG&E** – SDG&E's Home Energy Partnership Program offered rebates to customers who purchased and installed qualifying ENERGY STAR appliances in newly constructed single or multifamily homes, through participating design centers. It also offered incentives directly to builders who installed qualifying ENERGY STAR appliances in new housing projects. In addition, SDG&E offered comprehensive training to builders and other interested parties on a variety of topics related to energy codes and standards, residential design and construction, and energy analysis. Combined, SDG&E spent nearly $1.5 million annually on its residential new construction program efforts during PY2000-2001.

- **SCG** – Offered in PY2000-2001, SCG's Energy Advantage Homes Program was designed to promote ENERGY STAR features in single-family homes, and in particular to increase the use of high-performance heating and cooling ducting, and building commissioning. The budgets allocated for this program in PY2000 and PY2001 exceeded $4 million annually.

3.3.3 Education and Training Programs

The utilities are offering a number of programs in PY2002 classified as education and training programs. For example, the utilities have allocated over $7.5 million to the statewide Education and Training Services Program, which is an umbrella program designed to educate and promote energy conservation and efficiency by providing practical and easy to understand energy saving tips and information about rebate and incentive programs. This program aims to reach all residential and nonresidential customers and is associated with the State's Flex Your Power campaign.

Another significant avenue through which the utilities have historically sought to provide education and training services is the various energy centers. These energy centers are currently operated by PG&E, SCE and SCG. SDG&E had planned to open an energy center during PY2002. Generally, the energy centers incorporate training, outreach, education and tool development to educate customers about energy-efficient solutions and support the delivery of statewide and utility-specific energy-efficiency programs. The utilities have worked together to create a statewide program for the energy centers, including seminar/program coordination, a web-based energy-efficiency library, partnership program with third parties and/or other state agencies. During PY2000-2001, residential program funding for the utilities' energy centers totaled over $7 million. However, in PY2002, only PG&E and SDG&E have allocated residential program funding for these activities (approximately $4 million total).

In addition, the utilities have historically provided education and training services through their school programs. Together, the utilities' school-based energy-efficiency programs represent about $1.5 million in program funding in PY2002. Generally, the objectives of these programs are to raise awareness of teachers, facilities staff, students, and their families of the benefits of energy-efficiency habits and technologies and to reduce energy costs at the students' schools and homes.

3.3.4 Marketing and Outreach Programs

The utilities have allocated $10 million in PY2002 to the statewide Energy Efficiency Marketing and Outreach Program. With a particular focus on hard-to-reach customers, this effort is intended to provide accurate, unbiased energy-efficiency information that can be easily and cheaply accessed in a variety of languages and media formats. The objectives of this effort are to maximize residential and small business customer awareness of and participation in statewide energy-efficiency programs, to reduce customer energy bills and help the state of California avoid rolling outages, and to enhance the cost-effective delivery of energy-efficiency programs and services information to California customers.

4

METHODS

4.1 OVERVIEW

This section describes the specific steps and methods employed at each step of the analytical process that produced the results, which are presented in Sections 6 through 9. Combined Sections 2, 3, and 5, this section provides background for those results.

4.2 SUMMARY OF ANALYTICAL STEPS USED IN THIS STUDY

The crux of this study involves carrying out five analytical steps to produce estimates of the energy-efficiency potentials, which are presented in Sections 6 through 9 of this report. The basic analytical steps for this study are shown in relation to one another in Figure 4-1. The bulk of the analytical process for this study was carried out in a model developed by XENERGY for conducting energy-efficiency potential studies. Details on the steps employed and analyses conducted are described in Section 4.3. The spreadsheet model used, DSM ASSYST|, integrates technology-specific engineering and customer behavior data with utility market saturation data, load shapes, rate projections, and marginal costs into an easily updated data management system. The model itself is described in Appendix L.

The steps implemented in this study are described below; more detail is provided in the appendices.

Step 1: Develop Initial Input Data

- Develop list of energy-efficiency measure opportunities to include in scope
- Gather and develop technical data (costs and savings) on efficient measure opportunities
- Gather, analyze, and develop information on building characteristics, including total dwelling units, electricity and natural gas consumption and intensity by end use, end-use consumption load patterns by time of day and year (i.e., load shapes), market shares of key energy consuming equipment, and market shares of energy-efficiency technologies and practices.

Step 2: Estimate Technical Potential and Develop Supply Curves

- Match and integrate data on efficient measures to data on existing building characteristics to produce estimates of technical potential and energy-efficiency supply curves.

Step 3: Estimate Economic Potential

- Gather economic input data such as current and forecasted retail energy prices and current and forecasted costs of electricity generation and natural gas procurement, along with estimates of other potential benefits of reducing supply such as the value of reducing environmental impacts associated with energy production

- Match and integrate measure and building data with economic assumptions to produce indicators of costs from different viewpoints (e.g., societal and consumer)
- Estimate total economic potential based on the total resource cost test (reflecting a societal perspective.

Step 4: Estimate Maximum Achievable, Program, and Naturally Occurring Potentials

- Gather and develop estimates of program costs (e.g., for administration and marketing) and historic program savings
- Develop estimates of customer adoption of energy-efficiency measures as a function of the economic attractiveness of the measures, barriers to their adoption, and the effects of program intervention
- Estimate maximum achievable, program, and naturally occurring potentials
- Develop alternative economic estimates associated with alternative future scenarios.

Step 5: Scenario Analyses

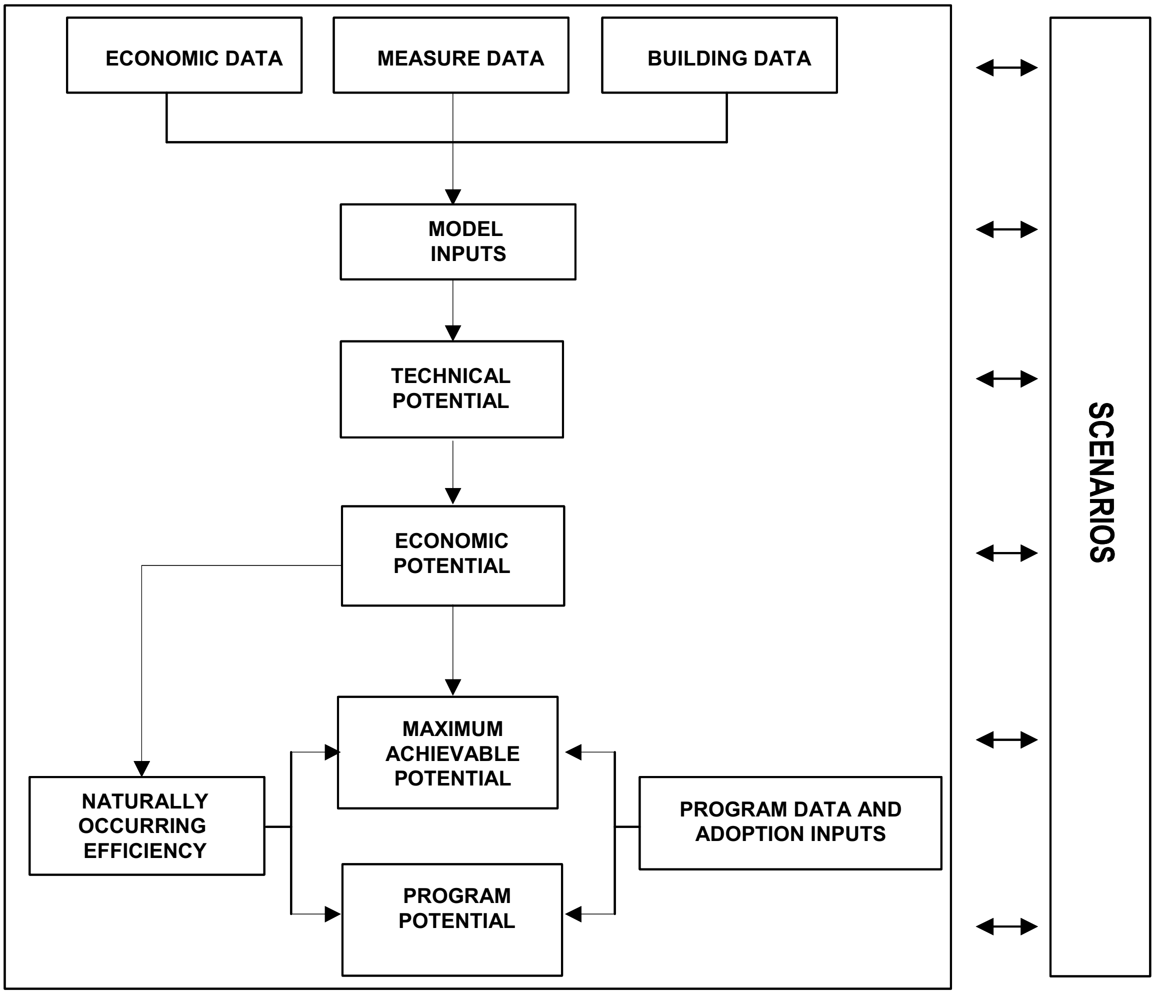
- Recalculate potentials under alternate economic scenarios.

4.3 STEP 1: DEVELOP INITIAL INPUT DATA

4.3.1 Development of Measure List

This subsection briefly discusses how we developed the list of energy-efficiency measures included in the study. Additional information is provided in Appendix A. The set of measures included in this potential study is shown in Table 4-1. To address the primary needs of program planners, the study scope was restricted to energy-efficiency measures and practices that are presently commercially available. These measures are of most immediate interest to energy-efficiency program planners. The study data, framework, and models can be easily changed, however, to include estimates of potential for emerging technologies. In addition, the scope of this study was focused on measures that could be relatively easily substituted for or applied to existing technologies on a retrofit basis. As a result, measures and savings that might be achieved through integrated redesign of existing energy-using systems, as might be possible during major renovations or remodels, are not included. This is another area in which the current results can be expanded upon. Finally, customer-behavior-related measures such as conservation activities are not addressed because their reliability and persistence are not proven.

Figure 4-1
Conceptual Overview of Study Process



The list of measures was developed by starting with the list of measures included in the *Database of Energy Efficient Resources* (*DEER) 2001 Update Study* (XENERGY 2001b), with some aggregation to prototypical applications. The measure list for the DEER Update study was developed in consultation with a CALMAC stakeholder group that included the major IOUs, California Energy Commission (CEC), and California Public Utilities Commission (CPUC). We then reviewed the 2002 program application filings of the major IOUs and other third parties to the CPUC and added measures that might have significant potential but were not on the *DEER 2001 Update Study* list.[1]

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[1] The *DEER Update 2001 Study* involved analysis of thousands of cost observations collected for residential and commercial measures.

Table 4-1
Measures Included in this Study

End Use	Energy-Efficiency Measures
Clothes dryers	High-efficiency clothes dryer with moisture sensors
Clothes washers	ENERGY STAR clothes washers, SEHA Tier 2 clothes washers
Dishwashers	ENERGY STAR dishwashers
Freezers	High-efficiency freezers
Lighting	Compact fluorescent lamps and T8 lamps with electronic ballast
Pools	High-efficiency pool pumps and motors
Refrigerators	ENERGY STAR refrigerators and early replacement of older refrigerators
Space conditioning	High-efficiency central and room air conditioners, thermal expansion valves (TXVs), ceiling fans, whole-house fans, attic venting, window film, double-pane low-E windows, window sunscreens, programmable thermostats, HVAC diagnostic testing and repair, duct repair, duct insulation, ceiling insulation, wall insulation, floor insulation, heat pumps, and condensing furnaces
Water heating	High-efficiency water heaters, heat pump water heaters, solar water heaters, low-flow showerheads, pipe wrap, faucet aerators, and water heater blankets, boiler controls

4.3.2 Technical Data on Efficient Measure Opportunities

Estimating the potential for energy-efficiency improvements requires a comparison of the costs and savings of energy-efficiency measures as compared to standard equipment and practices. Standard equipment and practices are often referred to in energy-efficiency analyses as *base cases*. Most of the measure cost data for this study was obtained from the *DEER 2001 Update Study*. Additional measure cost information was obtained from the work papers associated with the energy-efficiency program applications of the major IOUs and third parties for PY 2002, which can be downloaded from the CPUC website, as well as other secondary sources and interviews with industry experts.

Estimates of measure savings as a percentage of base equipment usage were developed from a variety of sources, including:

- Industry-standard engineering calculations
- Results from building energy simulation model analyses conducted for the *DEER 2001 Update Study*
- The California Conservation Inventory Group (CCIG) Technology Energy Savings Study (NEOS, 1994)
- The Measure Incentive and Cost Effectiveness Study for the California Residential Contractor Program (Mowris, 2000)
- Energy-efficiency program applications to the CPUC

- Secondary sources.

All measure cost and percentage savings estimates used in this study are shown in Appendices C and D.

4.3.3 Technical Data on Building Characteristics

As noted above, estimating the potential for energy-efficiency improvements involves comparison of the energy impacts of existing, standard-efficiency technologies with those of alternative high-efficiency equipment. This, in turn, dictates a relatively detailed understanding of the statewide energy characteristics of the existing marketplace. As described further in Section 4.4, a variety of data are needed to estimate the average and total savings potential for individual measures across the entire existing residential building population. The key data needed for our representation of the population of existing buildings included:

- Total number of the in-scope residential dwellings
- Annual energy consumption for each end use studied (both in terms of total consumption in kWh and therms and normalized for intensity on a per-dwelling basis
- End-use load shapes for electric end uses (that describe the amount of energy used or power demand over certain times of the day and days of the year)
- The saturation of electric and natural gas end uses (for example, the fraction of total residential dwellings with electric air conditioning)
- The market share of each base equipment type (for example, the fraction of total residential dwellings served by central air conditioners)
- Market share for each energy-efficiency measure in scope (for example, the fraction of residential dwellings already served by high-efficiency air conditioners).

Most of the data elements listed above were required at the utility service area and dwelling type level for this study. In addition, some key space conditioning data are required by climate zone. These key data elements are discussed briefly in the following subsections. More detailed documentation is provided in Appendices A through E.

Dwelling Counts and End-Use Energy Consumption

The primary source of dwelling counts and end-use energy consumption data was the CEC residential end-use forecasting database. In the end-use forecasting approach, end-use energy consumption is expressed as the product of the number of dwellings, the fraction of dwellings associated with a given end use (the end-use saturation), and the UEC (the unit energy consumption of an end use expressed in kWh or therms per home). Thus, energy use for end use *i* is calculated as:

$$EnergyUse_i = HH \times Saturation_i \times UEC_i$$

The three data elements have been collected and estimated from various sources over time and form the foundation upon which the CEC energy demand forecasts are developed. The base energy consumption estimates are shown in Section 2 of this report. Dwelling counts by building type are shown in Appendix E. Saturation and UEC data by base equipment type are documented in Appendix C.

Load Shapes, Energy and Peak Factors

Load shape data were used to develop energy and peak factors for the electric analysis. Energy and peak factors are used to allocate annual energy usage into utility costing periods and to provide estimates of peak demand based on cost period energy usage. The factors were developed by end use and dwelling type and were used to allocate measure impacts to utility costing periods. This is necessary because avoided-cost benefits (which are described later in this section) vary significantly by time of day, type of day, and month of year.

In the case of the electric energy factors, these factors are computed based on predefined costing periods (e.g., season, day of the week, and hours of the day) divided by annual energy use. The end result is a series of values for each period such that the sum of the periods is equal to 1.0. PG&E, SCE, and SDG&E typically use costing definitions that differ very slightly from each other. To maintain consistency of our study's results across the utilities, we choose one utility's costing periods to use for our analyses. The costing period definitions used for this study are shown in Table 4-2.

Table 4-2
Costing Period Definitions Used for Electric Energy Factors

	Season	
Period	Summer (May 1 - Oct 31)	Winter (All Other Months)
Peak	1 P.M. to 6 P.M. Weekdays	(none)
Partial-Peak	9 A.M. – 12 P.M. Weekdays 7 P.M. – 9 P.M. Weekdays	9 A.M. – 9 P.M. Weekdays
Off-Peak	10 P.M. – 8 A.M. Weekdays All Weekends and Holidays	10 P.M. to 8 A.M. Weekdays All Weekends and Holidays

The peak factors are based on the same predefined periods as the energy factors. In this case, the peak demand within a cost period is divided by the average demand within that same period; that is, the peak factor is the ratio of peak to average demand in a period. This is done for both noncoincident demands as well as for coincident demands. In the case of coincident demands, the time of coincidence was set to be the time at which the California electric system typically peaked within each marginal costing period. The most important of these periods, from a cost and reliability perspective is the Summer Peak Period. Our analysis indicated that 4 P.M. corresponded to the maximum system peak as registered by the California Independent System Operator in 2000. Our estimates of peak demand by end use were developed to correspond to a 4 P.M. system peak.

Further documentation of the sources used to develop these factors is provided in Appendix A. The factors developed and used in the study are shown in Appendix E.

Note that for the current study we are only estimating energy-efficiency potential for the residential sector for existing buildings. In addition, the majority of the data are from the CEC's energy forecast in 2000, which predated the unprecedented drop in peak demand and energy use that occurred in response to the energy crisis during the summer of 2001. As a result, our estimates of efficiency potential presented in this report are exclusive of voluntary, behavioral reductions, and efficiency improvements that occurred in 2001.

Base Technology Shares (Applicability Factors)

The technology or equipment mix within an end use determines the applicability of energy-efficiency measures for that end use. For example in the space cooling end use, high-efficiency central air conditioning measures are only applicable to the portion of the end use that is served by central air conditioning (as opposed to room air conditioning). For lighting, the technology shares distinguish between fixtures that accommodate bulbs (incandescent or CFL) versus those that accommodate fluorescent tubes.

The disaggregation of an end use into technology shares was only necessary for three residential end uses: space cooling, lighting, and multifamily gas water heating (which can be served through individual water heaters or through central boilers). Data on base technology shares were developed from several sources, as summarized in Table 4-3. A brief discussion of sources and development of technology share data follows.

Table 4-3
Data Sources for Technology Shares

End Use	Data Source
Lighting	California Baseline Lighting Efficiency Technology Report (HMG, 1997)
Space Cooling	CEC forecasting database
Multifamily Gas Water Heating	Statewide Survey of Multifamily Common Area Building Owners Market (ADM Associates, 2000)

The data sources listed in Table 4-3 are summarized below:

- The California Baseline Lighting Efficiency Technology Report. This study provided an analysis of detailed lighting data, including a breakdown of lighting fixture types and operating hours. These data were used to disaggregate the lighting end use into four component categories: 0.5 hour per day usage CFL-compatible fixtures, 2.5 hour per day CFL-compatible fixtures, 6.0 hour per day CFL-compatible fixtures, and T8-compatible fixtures.
- The CEC forecasting database. This data source, described above, splits the space cooling end use into three technology components: central air conditioning, room air conditioning, and evaporative coolers.

- The Statewide Survey of Multifamily Common Area Building Owners Market. This study included a survey of 541 apartment complexes throughout the state. Data from the survey pertinent to the residential potential analysis included the number of dwellings in complexes with gas boilers and the number of dwellings in complexes with gas boilers that did not have individual water heaters. This information was used to split the multifamily gas water heating end use into water heater and boiler components.

Existing Energy-Efficient Measure Saturations

To assess the amount of energy-efficiency savings available, estimates of the current saturation of energy-efficient measures are necessary. The primary source of data used for the measure saturation estimates were the Statewide Residential Lighting and Appliance Saturation Study (RLW, 2000) and the Residential Market Share Tracking Project (RER, 2001 and 2002). In some cases, judgmental adjustments to these saturation estimates were required to bring them up to date because the available sources were several years old. Adjustments were based on measure penetration estimates from the Market Share Tracking Study. Development of measure saturation data is discussed in more detail in Appendix A.

4.4 STEP 2: ESTIMATE TECHNICAL POTENTIAL AND DEVELOP ENERGY EFFICIENCY SUPPLY CURVES

As defined previously, **technical potential** refers to the amount of energy savings or peak demand reduction that would occur with the complete penetration of all measures analyzed in applications where they were deemed technically feasible from an engineering perspective. Total technical potential is developed from estimates of the technical potential of individual measures as they are applied to discrete market segments. Market segments in this study are the building types used in the CEC's demand forecasting models (e.g., offices, retail, etc.).

4.4.1 Core Equation

The core equation used to calculate the energy technical potential for each individual efficiency measure, by market segment, is shown below:

$$\text{Technical Potential of Efficient Measure} = \text{Total \# of Dwellings} \times \text{Base Case Equipment UEC} \times \text{Applicability Factor} \times \text{Not Complete Factor} \times \text{Feasibility Factor} \times \text{Savings Factor}$$

where:

- The **total number of dwelling units** applies to the particular market segment of interest.
- **Base-case equipment UEC** is the energy used per dwelling by each base-case technology in each market segment. This is the consumption of the energy-using equipment that the efficient technology replaces or affects. For example, if the efficient

measure were an efficient air conditioner, the base UEC would be the annual kWh per dwelling of an equivalent standard efficiency air conditioner.

- **Applicability factor** is the fraction of dwelling units that is applicable for the efficient technology in a given market segment, for the example above, the percentage dwellings with air conditioners.
- **Not complete factor** is the fraction of applicable dwelling units that has not yet been converted to the efficient measure; that is, (one minus the fraction of dwellings that already have the energy-efficiency measure installed).
- **Feasibility factor** is the fraction of the applicable dwelling units that is technically feasible for conversion to the efficient technology from an *engineering* perspective.
- **Savings factor** is the reduction in energy consumption resulting from application of the efficient technology.

Technical potential for peak demand reduction is calculated analogously.

An example of the core equation is shown in Table 4-4 for the case of a prototypical standard-efficiency air conditioner (10 SEER), which is replaced by a high-efficiency air conditioner (12 SEER) in the single-family segment in Climate Zone 7 of the SCE service territory.

Table 4-4
Example of Technical Potential Calculation
Replace 10 SEER Air Conditioner with 12 SEER Air Conditioner in the Single Family Segment of Climate Zone 7 of the SCE Service Territory

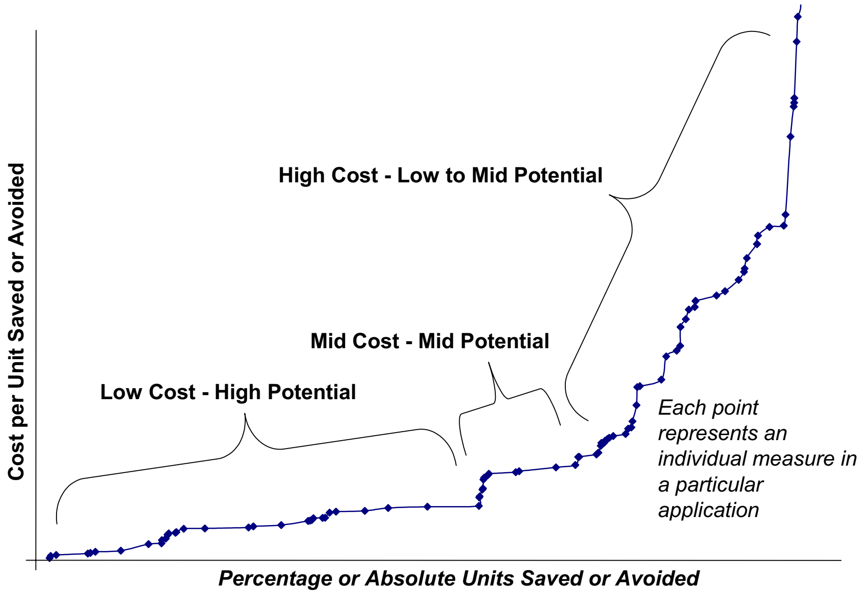
Technical Potential of Efficient Measure =	Total # of Dwellings	× Base Case Equipment UEC	× Applicability Factor	× Not Complete Factor	× Feasibility Factor	× Savings Factor
17.6 million kWh	130,990	2,563 kWh per dwelling	0.40	0.82	1.00	0.16

Technical energy-efficiency potential is calculated in two steps. In the first step, all measures are treated independently; that is, the savings of each measure are not marginalized or otherwise adjusted for overlap between competing or synergistic measures. By treating measures independently, their relative economics are analyzed without making assumptions about the order or combinations in which they might be implemented in customer buildings. However, the total technical potential across measures cannot be estimated by summing the individual measure potentials directly because some savings would be double-counted. For example, the savings from a measure that reduces heat gain into a building, such as ceiling insulation, are partially dependent on other measures that affect the efficiency of the system being used to cool the building, such as a high-efficiency air conditioner; the more efficient the air conditioner, the less energy saved from the application of the insulation, or vice versa.

4.4.2 Use of Supply Curves

In the second step cumulative technical potential is estimated using an energy-efficiency supply curve approach.[2] This method eliminates the double-counting problem. In Figure 4-2, we present a generic example of a supply curve. As shown in the figure, a supply curve typically consists of two axes—one that captures the cost per unit of saving a resource or mitigating an impact (e.g., $/kWh saved or $/ton of carbon avoided) and the other that shows the amount of savings or mitigation that could be achieved at each level of cost. The curve is typically built up across individual measures that are applied to specific base-case practices or technologies by market segment. Savings or mitigation measures are sorted on a least-cost basis, and total savings or impacts mitigated are calculated incrementally with respect to measures that precede them. Supply curves typically, but not always, end up reflecting diminishing returns, i.e., as costs increase rapidly and savings decrease significantly at the end of the curve.

Figure 4-2
Generic Illustration of Energy-Efficiency Supply Curve



As noted above, the cost dimension of most energy-efficiency supply curves is usually represented in dollars per unit of energy savings. Costs are usually annualized (often referred to as "levelized") in supply curves. For example, energy-efficiency supply curves usually present levelized costs per kWh or kW saved by multiplying the initial investment in an efficient technology or program by the "capital recovery rate" (CRR):

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[2] This section describes conservation supply curves as they have been defined and implemented in numerous studies. Readers should note that Stoft 1995 describes several technical errors in the definition and implementation of conservation supply curves in the original and subsequent conservation supply curve studies. Stoft concludes that conservation supply curves are not "true" supply curves in the standard economic sense but can still be useful (albeit with his recommended improvements) for their intended purpose (demonstration of cost-effective conservation opportunities).

$$\text{CRR} = \frac{d}{1-(1+d)^{-n}}$$

where d is the real discount rate and n is the number of years over which the investment is written off (i.e., amortized).

Thus,

Levelized Cost per kWh Saved = Initial Cost × CRR/Annual Electricity Savings

Levelized Cost per kW Saved = Initial Cost × CRR/Peak Demand Savings

Levelized Cost per Therm Saved = Initial Cost × CRR/Annual Natural Gas Savings

Table 4-5 shows a simplified numeric example of a supply curve calculation for several energy-efficiency measures applied to residential air conditioning for a hypothetical population of buildings. What is important to note is that in an energy-efficiency supply curve, the measures are sorted by relative cost: from least to most expensive. In addition, the energy consumption of the system being affected by the efficiency measures goes down as each measure is applied. As a result, the savings attributable to each subsequent measure decrease if the measures are interactive. For example, the high-efficiency air conditioner measure shown in Table 4-5 would save more at less cost per unit saved if it were applied to the base-case consumption before the ceiling insulation measure. Because ceiling insulation is more cost-effective, however, it is applied first, reducing the energy savings potential for the air conditioner. Thus, in a typical energy-efficiency supply curve, the base-case end-use consumption is reduced with each unit of energy-efficiency that is acquired. Notice in Table 4-5 that the total end-use GWh consumption is recalculated after each measure is implemented, thus reducing the base energy available to be saved by the next measure.

The example shown in Table 4-5 represents measures for one base-case technology in one market segment. These calculations are performed for all of the base-case technologies, market segments, and measure combinations in the scope of the study. The results are then ordered by levelized cost and the individual measure savings summed to produce the energy-efficiency potential for the entire sector (as presented in Section 6 of this report).

In the next subsection, we discuss how economic potential is estimated as a subset of the technical potential.

Table 4-5
Sample Technical Potential Supply Curve Calculation for Residential Air Conditioning
(*Note: Data are illustrative only*)

Measure	Total End Use Consumption of Population (GWh)	Applicable, Not Complete and Feasible Dwellings	Average kWh/dwelling of population	Savings %	GWh Savings	Levelized Cost ($/kWh saved)
Base Case: Standard-Efficiency Air Conditioner	294	100,000	2,941	N/A	N/A	N/A
1. Ceiling Insulation	294	18,000	2,941	26%	14	$0.02
2. High-Efficiency Air Conditioner	280	82,000	2,803	16%	37	$0.09
3. Whole-House Fans	244	90,000	2,435	9%	20	$0.34
With all measures	224		2,238	24%	70	

4.5 STEP 3: ESTIMATE ECONOMIC POTENTIAL

As introduced in Section 2, **economic potential** is typically used to refer to the technical potential of those energy conservation measures that are cost effective when compared to either supply-side alternatives or the price of energy. Economic potential takes into account the fact that many energy-efficiency measures cost more to purchase initially than do their standard-efficiency counterparts. The incremental costs of each efficiency measure are compared to the savings delivered by the measure to produce estimates of energy savings per unit of additional cost. These estimates of energy-efficiency resource costs can then be compared to estimates of other resources such as building and operating new power plants.

4.5.1 Cost Effectiveness Tests

To estimate economic potential, it is necessary to develop a measure by which it can be determined that a measure or program is economic. There is a large body of literature in which the merits of different approaches to calculating whether a public purpose investment in energy efficiency is cost effective are debated (Chamberlin and Herman 1993, RER 2000, Ruff 1988, Stoft 1995, and Sutherland 2000). In this report, we adopt the cost-effectiveness criteria used by the CPUC in its decisions regarding the cost-effectiveness of energy-efficiency programs funded under the State's public goods charge. The CPUC uses the total resource cost (TRC) test, as defined in the California Standard Practice Manual (CASPM 2001), to assess cost effectiveness. The TRC is a form of societal benefit-cost test. Other tests that have been used in analyses of program cost-effectiveness by energy-efficiency analysts include the Utility Cost, Ratepayer Impact Measure (RIM), and Participant tests. These tests are discussed in detail in the CASPM.

Before discussing the TRC test and how it is used in this study, we present below a brief introduction to the basic tests as described in the CASPM:[3]

- **Total Resource Cost Test**—The TRC test measures the net costs of a demand-side management program as a resource option based on the total costs of the program, including both the participants' and the utility's costs. The test is applicable to conservation, load management, and fuel substitution programs. For fuel substitution programs, the test measures the net effect of the impacts from the fuel not chosen versus the impacts from the fuel that is chosen as a result of the program. TRC test results for fuel substitution programs should be viewed as a measure of the economic efficiency implications of the total energy supply system (gas and electric). A variant on the TRC test is the Societal Test. The Societal Test differs from the TRC test in that it includes the effects of externalities (e.g. environmental, national security), excludes tax credit benefits, and uses a different (societal) discount rate.
- **Participant Test**—The Participant test is the measure of the quantifiable benefits and costs to the customer due to participation in a program. Since many customers do not base their decision to participate in a program entirely on quantifiable variables, this test cannot be a complete measure of the benefits and costs of a program to a customer.
- **Utility (Program Administrator) Test**—The Program Administrator Cost test measures the net costs of a demand-side management program as a resource option based on the costs incurred by the program administrator (including incentive costs) and excluding any net costs incurred by the participant. The benefits are similar to the TRC benefits. Costs are defined more narrowly.
- **Ratepayer Impact Measure Test**—The Ratepayer Impact Measure (RIM) test measures what happens to customer bills or rates due to changes in utility revenues and operating costs caused by the program. Rates will go down if the change in revenues from the program is greater than the change in utility costs. Conversely, rates or bills will go up if revenues collected after program implementation are less than the total costs incurred by the utility in implementing the program. This test indicates the direction and magnitude of the expected change in customer bills or rate levels.

The key benefits and costs of the various cost-effectiveness tests are summarized in Table 4-6.

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[3] These definitions are direct excerpts from the California Standard Practice Manual, October 2001.

Table 4-6
Summary of Benefits and Costs of California Standard Practice Manual Tests

Test	Benefits	Costs
TRC Test	Generation, transmission and distribution savings Participants avoided equipment costs (fuel switching only)	Generation costs Program costs paid by the administrator Participant measure costs
Participant Test	Bill reductions Incentives Participants avoided equipment costs (fuel switching only)	Bill increases Participant measure costs
Utility (Program Administrator) Test	Generation, transmission and distribution savings	Generation costs Program costs paid by the administrator Incentives
RIM Test	Generation, transmission and distribution savings Revenue gain	Generation costs Revenue loss Program costs paid by the administrator Incentives

Generation, transmission, and distribution savings (hereafter, energy benefits) are defined as the economic value of the energy and demand savings stimulated by the interventions being assessed. These benefits are typically measured as induced changes in energy consumption, valued using some mix of avoided costs. Statewide values of avoided costs are prescribed for use in implementing the test. Electricity benefits are valued using three types of avoided electricity costs: avoided distribution costs, avoided transmission costs, and avoided electricity generation costs.

Participant costs are comprised primarily of incremental measure costs. Incremental measure costs are essentially the costs of obtaining energy efficiency. In the case of an add-on device (say, a water heater blanket or ceiling insulation), the incremental cost is simply the installed cost of the measure itself. In the case of equipment that is available in various levels of efficiency (e.g., a central air conditioner), the incremental cost is the excess of the cost of the high-efficiency unit over the cost of the base (reference) unit.

Administrative costs encompass the real resource costs of program administration, including the costs of administrative personnel, program promotions, overhead, measurement and evaluation, and shareholder incentives. In this context, administrative costs are not defined to include the costs of various incentives (e.g., customer rebates and salesperson incentives) that may be offered to encourage certain types of behavior. The exclusion of these incentive costs reflects the fact that they are essentially transfer payments. That is, from a societal perspective they involve offsetting costs (to the program administrator) and benefits (to the recipient).

4.5.2 Use of the TRC Test to Estimate Economic Potential

We use the TRC test in two ways in this study. First, we develop an estimate of economic potential by calculating the TRC of individual measures and applying the methodology described below. Second, we develop estimates of whether different program scenarios are cost effective as described in Section 4.6.

Economic potential can be defined either inclusively or exclusively of the costs of programs that are designed to increase the adoption rate of energy-efficiency measures. In this study, we define economic potential to *exclude* program costs. We do so primarily because program costs are dependent on a number of factors that vary significantly as a function of program delivery strategy. There is no single estimate of program costs that would accurately represent such costs across the wide range of program types and funding levels possible. Once an assumption is made about program costs, one must also link those assumptions to expectations about market response to the types of interventions assumed. Because of this, we believe it is more appropriate to factor program costs into our analysis of maximum achievable and program potential (as will be described in Section 4.6).

As implied in Table 4-6 and defined in the CASPM 2001, the TRC focuses on resource savings and counts benefits as utility avoided supply costs and costs as participant costs and utility program costs. It ignores any impact on rates. It also treats financial incentives and rebates as transfer payments; i.e., the TRC is not affected by incentives. The somewhat simplified benefit and cost formulas for the TRC are presented in Equations 4-1 and 4-2.

$$\text{Benefits} = \sum_{t=1}^{N} \frac{\text{Avoided Costs of Supply}_{p,t}}{(1+d)^{t-1}} \qquad \textbf{Eqn. 4-1}$$

$$\text{Costs} = \sum_{t=1}^{N} \frac{\text{Program Cost}_{t} + \text{Participant Cost}_{t}}{(1+d)^{t-1}} \qquad \textbf{Eqn. 4-2}$$

where

d = the discount rate
p = the costing period
t = time (in years)
n = 20 years

The discount rate used is 8 percent, as required by the CPUC for program filings by major IOUs in 2001.[4] We use a *normalized* measure life of 20 years to capture the benefit of long-lived

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[4] We recognize that the 8-percent discount is much lower than the implicit discount rates at which customers are observed to adopt efficiency improvements. This is by intent since we seek at this stage of the analysis to estimate the potential that is cost-effective from primarily a societal perspective. The effect of implicit discount rates is incorporated into our estimates of achievable program and naturally occurring potential.

measures. Measures with measure lives shorter than 20 years are "re-installed" in our analysis as many times as necessary to reach the normalized 20-year life of the analysis.

The avoided costs of supply are calculated by multiplying measure energy savings and peak demand impacts by per-unit avoided costs by costing period.[5] Energy savings are allocated to costing periods and peak impacts estimated using the load shape factors discussed in Section 4.3.3 and shown in Appendix E.

As noted previously, in the measure-level TRC calculation used to estimate economic potential, program costs are excluded from Equation 4-2. Using the supply curve methodology discussed previously, measures are ordered by TRC (highest to lowest) and then the economic potential is calculated by summing the energy savings for all of the technologies for which the marginal TRC test is greater than 1.0. In the example in Table 4-7, the economic potential would include the savings for Measures 1 and 2, but exclude saving for Measure 3 because the TRC is less than 1.0 for Measure 3. The supply curve methodology, when combined with estimates of the TRC for individual measures, produces estimates of the economic potential of efficiency improvements from a societal perspective. By definition and intent, this estimate of economic potential is a theoretical quantity that will exceed the amount of potential we estimate to be achievable through program activities in the final steps of our analyses.

In this study we calculate economic potential for three scenarios, which capture different assumptions about future avoided supply costs and residential rates. These scenarios and their associated avoided-cost and rate forecasts are described in Section 5.

Table 4-7
Sample Use of Supply Curve Framework to Estimate Economic Potential
(*Note: Data are illustrative only*)

Measure	Total End Use Consumption of Population (GWh)	Applicable, Not Complete and Feasible Dwellings	Average kWh/dwelling of population	Savings %	GWh Savings	TRC Test	Savings Included in Economic Potential
Base Case: Standard-Efficiency AC	294	100,000	2,941	N/A	N/A	N/A	N/A
1. Ceiling Insulation	294	18,000	2,941	26%	14	10.8	Yes
2. High-Efficiency AC	280	82,000	2,803	16%	37	2.3	Yes
3. Whole-House Fans	244	90,000	2,435	9%	20	0.4	No
Technical Potential with all measures				24%	70		
Economic Potential with measures where TRC > 1.0				17%	51		

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[5] The per-unit avoided-cost values used in this study are shown in Section 5 and Appendix B.

4.6 STEP 4: ESTIMATE MAXIMUM ACHIEVABLE, PROGRAM, AND NATURALLY OCCURRING POTENTIALS

In this section we present the method we employ to estimate the fraction of the market that adopts each energy-efficiency measure in the presence and absence of energy-efficiency programs. In Section 1 of this report we introduced the concepts of maximum achievable, program, and naturally occurring potentials. We defined:

- **Maximum achievable potential** as the amount of economic potential that could be achieved over time under the most aggressive program scenario possible.
- **Program potential** as the amount of savings that would occur in response to one or more specific market interventions.
- **Naturally occurring potential** as the amount of savings estimated to occur as a result of normal market forces, that is, in the absence of any utility or governmental intervention.

Our estimates of program potential are the most important results of this study. Estimating technical, economic, and maximum achievable potentials are necessary steps in the process from which important information can be obtained; however, the end goal of the process is better understanding how much of the remaining potential can be captured in programs, whether it would be cost-effective to increase program spending, and how program costs may be expected to change in response to measure adoption over time.

The assumptions and data inputs used for the specific scenarios developed for this study are described in Section 5.

4.6.1 Adoption Method Overview

We use a method of estimating adoption of energy-efficiency measures that applies equally to our program and naturally occurring analyses. Whether as a result of natural market forces or aided by a program intervention, the rate at which measures are adopted is modeled in our method as a function of the following factors:

- The availability of the adoption opportunity as a function of capital equipment turnover rates and changes in building stock over time
- Customer awareness of the efficiency measure
- The cost-effectiveness of the efficiency measure
- Market barriers associated with the efficiency measure.

The method we employ is executed in the measure penetration module of XENERGY's DSM ASSYST model, which is described in more detail in Appendix L.

In this study, only measures that pass the measure-level TRC test discussed under Section 4.5 are put into the penetration module for estimation of customer adoption.

Availability

A crucial part of the model is a stock accounting algorithm that handles capital turnover and stock decay over a period of up to 20 years. In the first step of our achievable potential method, we first calculate the number of customers for whom each measure will apply. The input to this calculation is the total number of dwellings available for the measure from the technical potential analysis described in Section 4.4, i.e., the total number of dwellings multiplied by the Applicability, Not Complete, and Feasibility factors described previously. We call this the eligible stock. The stock algorithm keeps track of the number of dwellings available for each efficiency measure in each year based on the total eligible stock and whether the application is new construction, retrofit, or replace-on-burnout.[6]

Retrofit measures are available for implementation by the entire eligible stock. The eligible stock is reduced over time as a function of adoptions[7] and building decay.[8] Replace-on-burnout measures are available only on an annual basis, approximated as equal to the inverse of the service life.[9] The annual portion of the eligible market that does not accept the replace-on-burnout measure does not have an opportunity again until the end of the service life.

Awareness

In our modeling framework, customers cannot adopt an efficient measure merely because there is stock available for conversion. Before they can make the adoption choice, they must be aware and informed about the efficiency measure. Thus, in the second stage of the process, the model calculates the portion of the available market that is informed. An initial user-specified parameter sets the initial level of awareness for all measures. Incremental awareness occurs in the model as a function of the amount of money spent on awareness/information building and how well those information-building resources are directed to target markets. User-defined program characteristics determine how well information-building money is targeted. Well-targeted programs are those for which most of the money is spent informing only those customers that are in a position to implement a particular group of measures. Untargeted programs are those in which advertising cannot be well focused on the portion of the market that is available to implement particular measures. The penetration module in DSM ASSYST has a target effectiveness parameter that is used to adjust for differences in program advertising efficiency associated with alternative program types.

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[6] Replace-on-burnout measures are defined as the efficiency opportunities that are available only when the base equipment turns over at the end of its service life. For example, a high-efficiency air conditioner measure is usually only considered at the end of the life of an existing air conditioner. By contrast, retrofit measures are defined to be constantly available, for example, application of a water heater blanket to an existing water heater.

[7] That is, each dwelling that adopts the retrofit measure is removed from the eligible stock for retrofit in the subsequent year.

[8] Buildings do not last forever. An input to the model is the rate of decay of the existing dwellings. Dwellings typically decay at a very slow rate.

[9] For example, a base-case technology with a service life of 15 years is only available for replacement to a high-efficiency alternative each year at the rate of 1/15 times the total eligible stock. For example, the fraction of the market that does not adopt the high-efficiency measure in year *t* will not be available to adopt the efficient alternative again until year $t + 15$.

The model also controls for information retention. An information decay parameter in the model is used to control for the percentage of customers that will retain program information from one year to the next. Information retention is based on the characteristics of the target audience and the temporal effectiveness of the marketing techniques employed.

Adoption

The portion of the total market that is available and informed can now face the choice of whether or not to adopt a particular measure. Only those customers for whom a measure is available for implementation (Stage 1) and, of those customers, only those who have been informed about the program/measure (Stage 2), are in a position to make the implementation decision.

In the third stage of our penetration process, the model calculates the fraction of the market that adopts each efficiency measure as a function of the Participant test. The Participant test is a benefit-cost ratio that is calculated in this study as follows:

$$\text{Benefits} = \sum_{t=1}^{N} \frac{\text{Customer Bill Savings } (\$)_t}{(1+d)^{t-1}} \qquad \textbf{Eqn. 4-3}$$

$$\text{Costs} = \sum_{t=1}^{N} \frac{\text{Participant Costs } (\$)_t}{(1+d)^{t-1}} \qquad \textbf{Eqn. 4-4}$$

where

d = the discount rate
t = time (in years)
n = 20 years

We use a normalized measure life of 20 years to capture the benefits associated with long-lived measures. Measures with lives shorter than 20 years are “re-installed” in our analysis as many times as necessary to reach the normalized 20-year life of the analysis.

The bill reductions are calculated by multiplying measure energy savings and customer peak demand impacts by retail energy and demand rates.[10]

The model uses measure implementation curves to estimate the percentage of the informed market that will accept each measure based on the participant’s benefit-cost ratio. The model provides enough flexibility so that each measure in each market segment can have a separate implementation rate curve. The functional form used for the implementation curves is:

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[10] The retail rate values used in this study are shown in Section 5 and Appendix B.

$$y = \frac{a}{\left(1+e^{-\ln\frac{x}{4}}\right) \times \left(1+e^{-c\ln(bx)}\right)}$$

where:

y = the fraction of the market that installs a measure in a given year from the pool of informed applicable customers;

x = the customer's benefit-cost ratio for the measure;

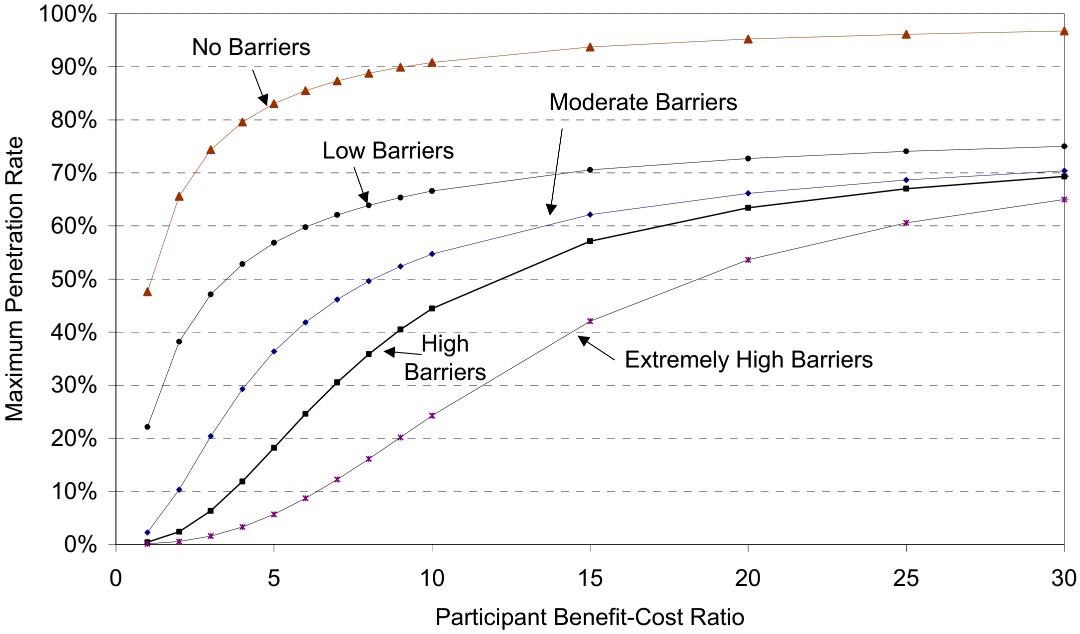
a = the maximum annual acceptance rate for the technology;

b = the inflection point of the curve. It is generally 1 over the benefit-cost ratio that will give a value of 1/2 the maximum value; and

c = the parameter that determines the general shape (slope) of the curve.

The primary curves utilized in this study are shown in Figure 4-3. These curves produce base-year program results that are calibrated to actual measure implementation results associated with major IOU residential efficiency programs over the past several years.

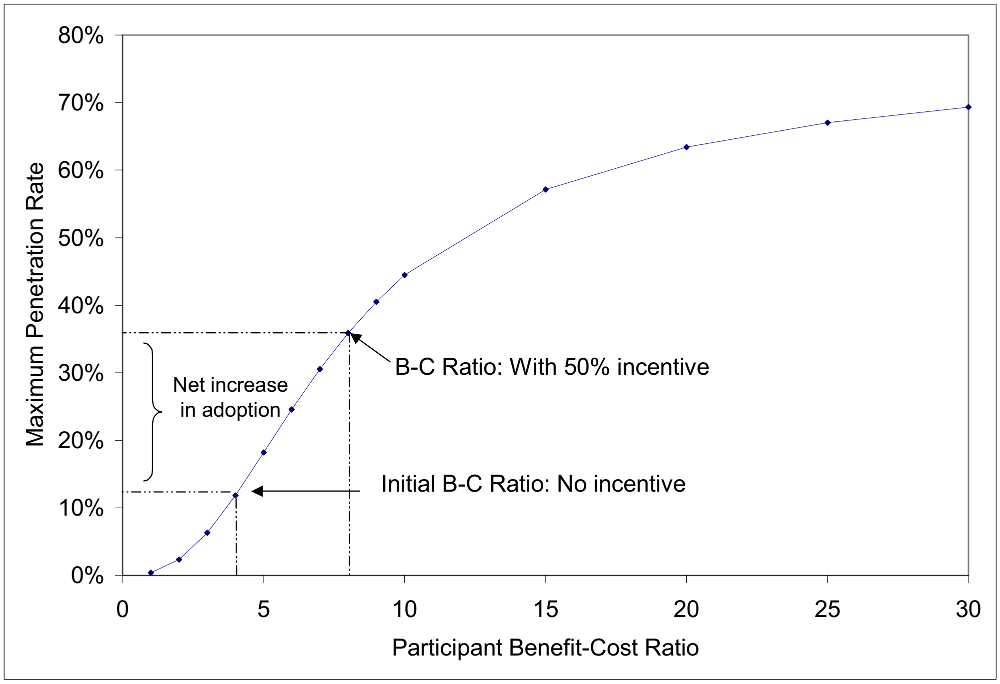
Figure 4-3
Primary Measure Implementation Curves Used in Adoption Model



Note that for the moderate, high barrier, and extremely high curves, the participant benefit-cost ratios have to be very high before significant adoption occurs. This is because the participant benefit-cost ratios are based on a 15-percent discount rate. This discount rate reflects likely adoption if there were no market barriers or market failures, as reflected in the no-barriers curve in the figure. Experience has shown, however, that actual adoption behavior correlates with implicit discount rates several times those that would be expected in a perfect market.[11]

The model estimates adoption under both naturally occurring and program intervention situations. There are only two differences between the naturally occurring and program analyses. First, in any program intervention case in which measure incentives are provided, the Participant benefit-cost ratios are adjusted based on the incentives. Thus, if an incentive that pays 50 percent of the incremental measure cost is applied in the program analysis, the Participant benefit-cost ratio for that measure will double (since the costs have been halved). The effect on the amount of adoption estimated will depend on where the pre- and post-incentive benefit-cost ratios fall on the curve. This effect is illustrated in Figure 4-4.

Figure 4-4
Illustration of Effect of Incentives on Adoption Level as Characterized in Implementation Curves



In this study, as discussed in Section 5, achievable potential energy-efficiency forecasts were developed for several scenarios ranging from base levels of program intervention, through moderate levels, up to an aggressive energy-efficiency acquisition scenario. Uncertainty in rates and avoided costs were also characterized in alternate scenarios. The final results produced are

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[11] For some, it is easier to consider adoption as a function of simple payback. However, the relationship between payback and the participant benefit-cost ratio varies depending on measure life and discount rate. For a long-lived measure of 15 years with a 15-percent discount rate, the equivalent payback at which half of the market would adopt a measure is roughly 6 months, based on the high barrier curve in Figure 4-3. At a 1-year payback, one-quarter of the market would adopt the measure. Adoption reaches near its maximum at a 3-month payback. The curves reflect the real-world observation that implicit discount rates can average up to 100 percent.

annual streams of achievable program impacts (energy and demand by time-of-use period) and all societal and participant costs (program costs plus end-user costs). Model results and outputs are shown in Sections 8 and 9 and Appendix J.

4.7 MODELING CAVEATS

Because models are, by design, a simplification of reality, there will always be limitations associated with any model-based analysis. Following are some key modeling limitations the reader of this report should be aware of:

- **Aggregation bias** occurs because each market segment in the study is characterized using average values for that segment (for UECs, end use, and energy-efficiency measure saturations, etc.), and customers who vary from the average may not always be well represented by the average result. For example, some water-heating measures may be cost effective in homes with large water-heating requirements (due to factors such as large family sizes), although they are not cost effective in the average home. Some space-heating or cooling measures may be cost effective in the most extreme areas within a given climate zone, although they are not cost effective based on average heating and cooling conditions within the climate zone. To minimize aggregation bias, we have utilized a relatively large number of market segments (6 building types across 14 climate zones) to characterize residential customers.
- **Competing technologies** are not modeled simultaneously with our model. Rather, the technology that is associated with the highest TRC value is utilized as a proxy for all competing technologies. While this approach screens out some technologies that are present, and should be present, in the marketplace, it still provides a reasonable estimate of energy savings potential attributable to all the related technologies.
- **Fuel types** (electricity and natural gas) are modeled independently and adjustments must be made to assess measures (such as ceiling insulation) that can affect both fuels. To ensure cost-effectiveness calculations are correct with multi-fuel measures, we prorate measure costs based on the net present value of avoided-cost benefits that accrue to each fuel type.
- **Penetration curves** used to estimate achievable potentials are, as with all similar potential models, based on limited real-world experience. While we calibrate our models to recent program data, we acknowledge increased uncertainty in model results when we simulate our models under advanced-funding scenarios where limited real-world data exist.
- **Awareness levels** are driven by estimates of the costs associated with making household decision-makers informed enough to make efficiency-related decisions. Empirical data is often unavailable in the form necessary for these estimates.

5

SCENARIO DEVELOPMENT

5.1 INTRODUCTION

In this chapter, we describe scenarios for which we estimate energy-efficiency potential in this study. This section is closely tied to Section 4 in which we present the methods used in this study.

Scenario analysis is a tool commonly used to address uncertainty, which is inherent to forecasts. By constructing alternative scenarios, one can examine the sensitivity or robustness of one's predictions to changes in key underlying assumptions.

We construct scenarios of energy-efficiency potential for two key reasons. First, our estimates of potential are forecasts of future adoptions of energy-efficiency measures that are a function of data inputs and assumptions that are themselves forecasts. For example, as described in Section 4, our estimates of potential depend on estimates of measure availability, measure costs, measure savings, measure saturation levels, electricity and natural gas rates, and avoided costs. Each of the inputs to our analysis is subject to some uncertainty, though the amount of uncertainty varies among the inputs.

The second key reason that we construct scenarios is that the final quantity with which we are most interested in this study, achievable potential, is by definition extremely mutable. Achievable potential is dependent on the level of resources and types of strategies employed to increase the level of measure adoption beyond what would otherwise occur. In California, the level of resources and types of strategies are determined by policies and objectives of the institutions charged with enabling, governing, and administering public purpose energy-efficiency programs.[1] As illustrated in Section 3, funding levels for energy efficiency have changed dramatically over time.

Thus, we chose to develop scenarios to address uncertainty in factors over which one has limited direct control (e.g., future avoided costs and rates) as well as those that are controllable by definition (e.g., efficiency program funding levels).

5.2 SCENARIO ELEMENTS

As noted above, although there is uncertainty associated with virtually all of the inputs to our estimates of energy-efficiency potential, the level of uncertainty varies among inputs and not all

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[1] The minimum funding level for efficiency programs is determined by the public goods charge (PGC) authorized in Senate Bill (SB) 1194 and signed into law by Governor Gray Davis in 2000. Under SB 1194, the major investor-owned utilities (IOUs) in California are required to collect the PGC through a surcharge on customer bills. The California Public Utilities Commission (CPUC) has regulatory authority over how the IOUs administer the energy-efficiency funds.

inputs are equally important to the final results. In addition, the number of scenarios and amount of uncertainty analysis that can or should be conducted is partly limited by the resources available for this study.[2] We determined that the greatest uncertainty in our estimates of economic and achievable potential, which are considered of more policy importance than estimates of technical potential, is that associated with future wholesale and retail energy prices and future program funding levels. As a result, we limited the current scenario analyses for the current study to these two dimensions. Each dimension, energy cost and funding level, is referred to as a scenario element. As discussed below, we developed three energy cost elements and four program funding level elements. These elements are then combined into 12 achievable-potential scenarios, as summarized in Table 5-1.

Table 5-1
Matrix of the 12 Achievable Potential Scenarios

	Energy Cost Element		
Program Funding Level Element	**Base**	**Low**	**High**
Level 1: Continued at current funding levels	Base/Level 1	Low/Level 1	High/Level 1
Level 2: 50% increase from current funding levels	Base/Level 2	Low/Level 2	High/Level 2
Level 3: 100% increase from current funding levels	Base/Level 3	Low/Level 3	High/Level 3
Level 4: Sufficient funding for maximum achievable	Base/Level 4	Low/Level 4	High/Level 4

5.2.1 Energy Cost Elements

This study was conducted in mid-2002, a period just following the recent California energy crisis. The advent of the energy crisis created considerable uncertainty in industry estimates of wholesale electricity prices and rates for the three electric IOUs. As a result, we created three future energy cost scenario elements: Base, Low, and High.

Base Energy Cost Element

Base avoided electricity costs are shown in Figure 5-1, avoided electric distribution costs are shown in Figure 5-2. As would be expected, the forecast cost per kWh is substantially higher for the Summer On-Peak and is expected to continue to more than double over the next 20 years, while the cost for the other periods raises much more slowly. Avoided natural gas costs are shown in Figure 5-3, which are also expected to continue to rise over the next 20 years. The base avoided-cost values also are provided in Appendix B.

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[2] Recall that the primary objective of this study is to update estimates of potential that had not been estimated in over 5 years. Scenario analysis was an important but initially secondary objective. We expect that additional scenario and uncertainty analyses may be conducted in the near future on related subsequent studies.

Figure 5-1
Base Avoided Electricity Costs

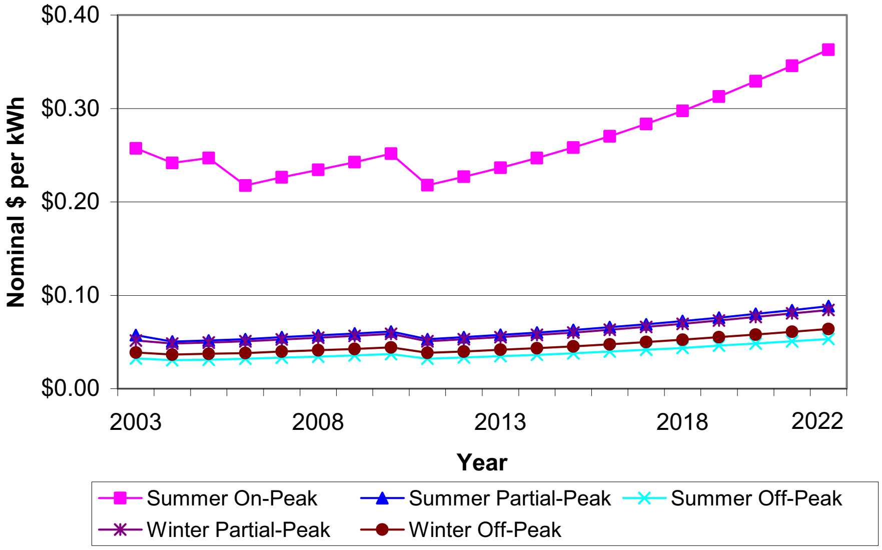


Figure 5-2
Base Avoided Electric Transmission and Distribution Costs

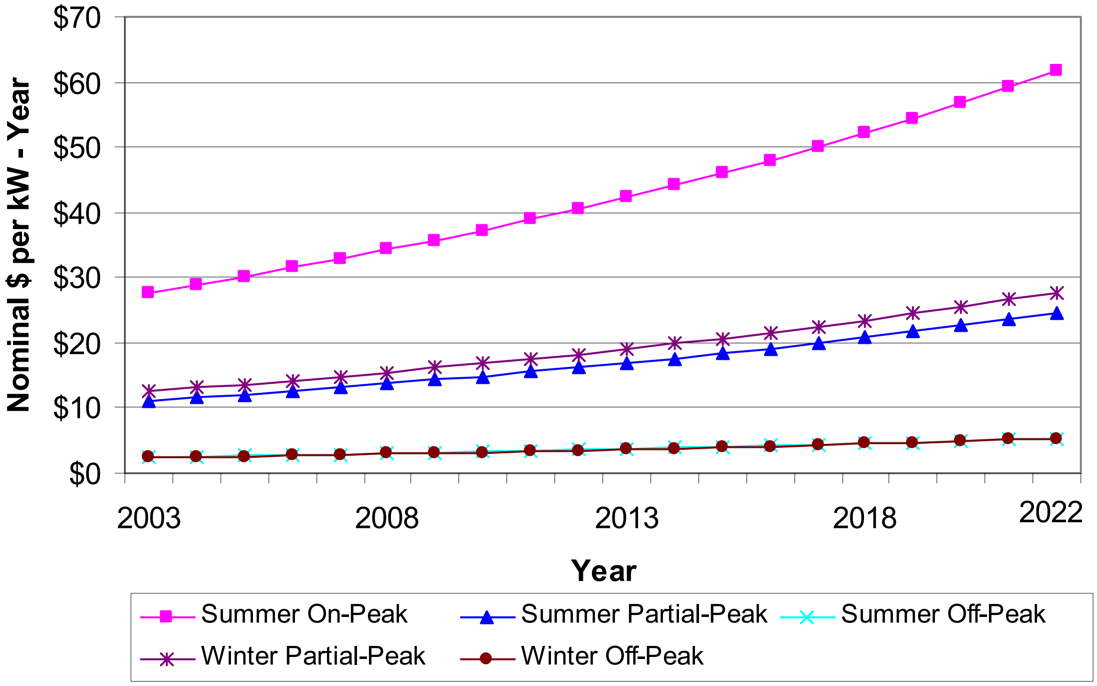
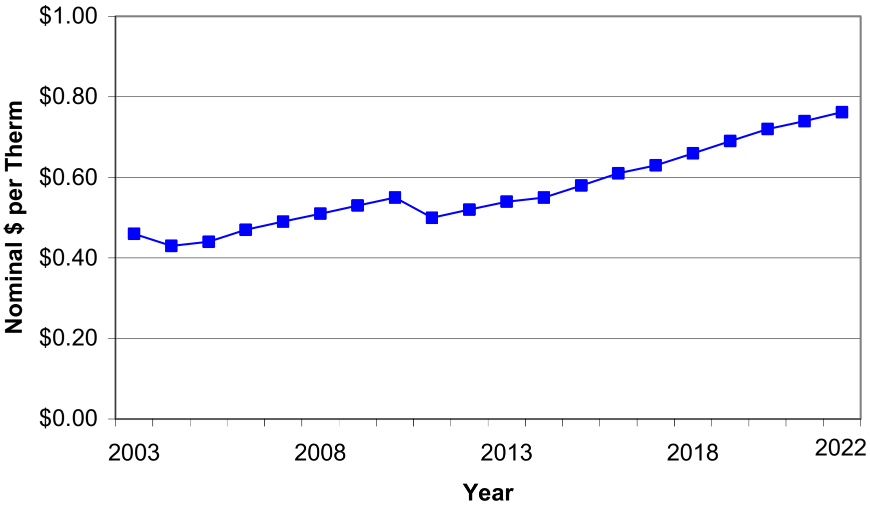


Figure 5-3
Base Avoided Natural Gas Costs



The Base electric avoided-cost values range from 3.5 to 19 cents per kWh saved per year over the 20-year forecast period, depending on the end use of interest.[3] The base natural gas avoided-cost values average 55 cents per therm, which are higher than gas costs seen in the 1990's but lower than those experienced during the recent energy crisis.

The Base residential electric rate forecast used in this study is shown in Figure 5-4. We used an average rate for residential customers in California. Current residential rates are roughly 20 percent higher than frozen tariffs in place between 1998 and the first half of 2001. The Base scenario rate forecast starts out at current levels and then declines by an average of 4 percent per year in real terms over the period 2003 to 2012. This rate forecast was obtained from the California Energy Commission's (CEC's) most recent price forecast update (dated July 19, 2002 and posted on the CEC's web site).

The base natural gas rate forecast is shown in Figure 5-5. We benchmarked this forecast to average residential natural gas prices in California for 2002 and applied growth rates from the avoided gas cost forecast to project these rates out into the future.

The base energy cost element is summarized in Table 5-2.

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[3] The value of avoided-cost savings range as a function of the load shape of the end use from which savings are achieved.

Figure 5-4
Base Run Residential Electric Rate Forecast

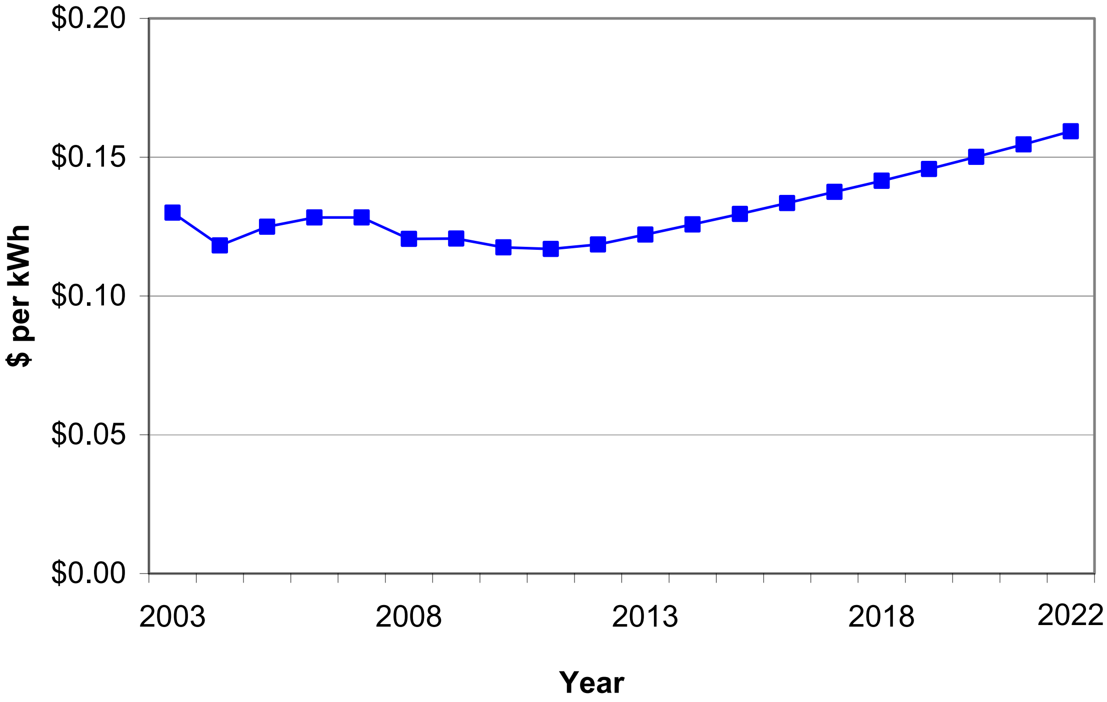

Figure 5-5
Base Run Residential Natural Gas Rate Forecast

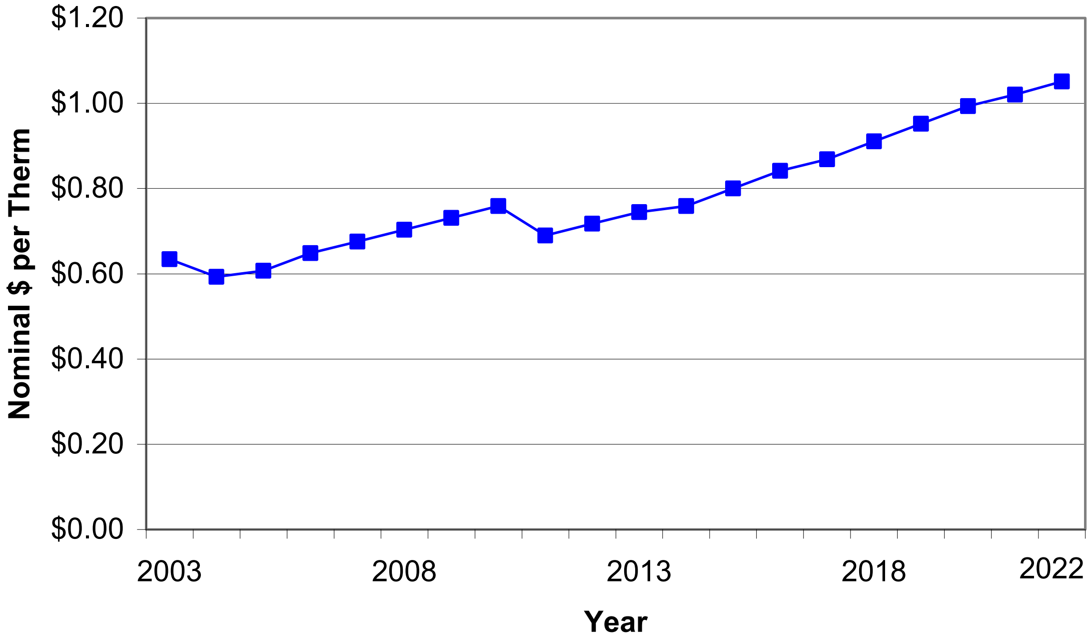

Table 5-2
Summary of Base Energy Cost Element

Fuel	Cost Type	Description	Source
Electricity	Avoided Costs	Annual avoided-cost averages roughly 3.5 to 19 cents per kWh depending on the end use affected. See Figures 5-1 and 5-2 and Appendix B for specific values.	CPUC authorized avoided costs for major IOUs 2001 and 2002 cost-effectiveness analyses (CPUC 2000).
	Residential Rates	Estimates of current average residential IOU rates that decline by 4 percent per year in real terms over the 2003-2012 period.	CEC 2002. CEC's most recent residential price forecast (dated July 19, 2002).
Natural Gas	Avoided Costs	Annual avoided-cost averages 46 cents per therm and remains relatively unchanged in real terms throughout the forecast horizon.	CPUC authorized avoided costs for 2002 program cost-effectiveness analyses (CPUC 2001).
	Residential Rates	Annual average rate of 63 cents per therm in 2003 that remains relatively flat, in real terms, throughout the forecast horizon.	EIA average residential prices for California, 12 months ending March 2000; CPUC authorized avoided costs for 2002 program cost-effectiveness analyses (CPUC 2001).

Low and High Energy Cost Elements

Because of the tremendous uncertainty around estimates of future wholesale and retail energy costs in California, we developed both Low and High energy cost scenario elements as alternatives to the Base energy cost scenario element. The purpose of developing the Low and High energy cost elements of our scenarios is to bound the Base energy costs by two moderately extreme cases. Although many different combinations of alternative future avoided costs and rates are possible, we choose to create two simple cases.

For both electric and gas analyses, the Low avoided energy costs are simply half of the Base scenario avoided costs throughout the forecast period. For electricity, the High avoided costs were set at 25 percent above the Base avoided costs throughout the forecast period. For natural gas, the High avoided costs were set at 50 percent above the base avoided costs.

The Low residential electric rates were set at two cents per kWh below the Base rates. In the High element, current residential electric rates continue to rise by inflation throughout the forecast period; that is, the energy-crisis related rate increases of 2001 are permanent in the High element. Figure 5-6 illustrates the residential electric rates by energy cost scenario. Low residential natural gas rates were set at 50 percent of the Base rates, and High natural gas rates were set at 50 percent above the Base rates. Figure 5-7 illustrates the residential natural gas rates by energy cost scenario.

The actual avoided-cost and retail rate values for the Low and High elements are proved in Appendix A. A summary of these elements is provided in Table 5-3.

Figure 5-6
Residential Electric Rates by Energy Cost Scenario

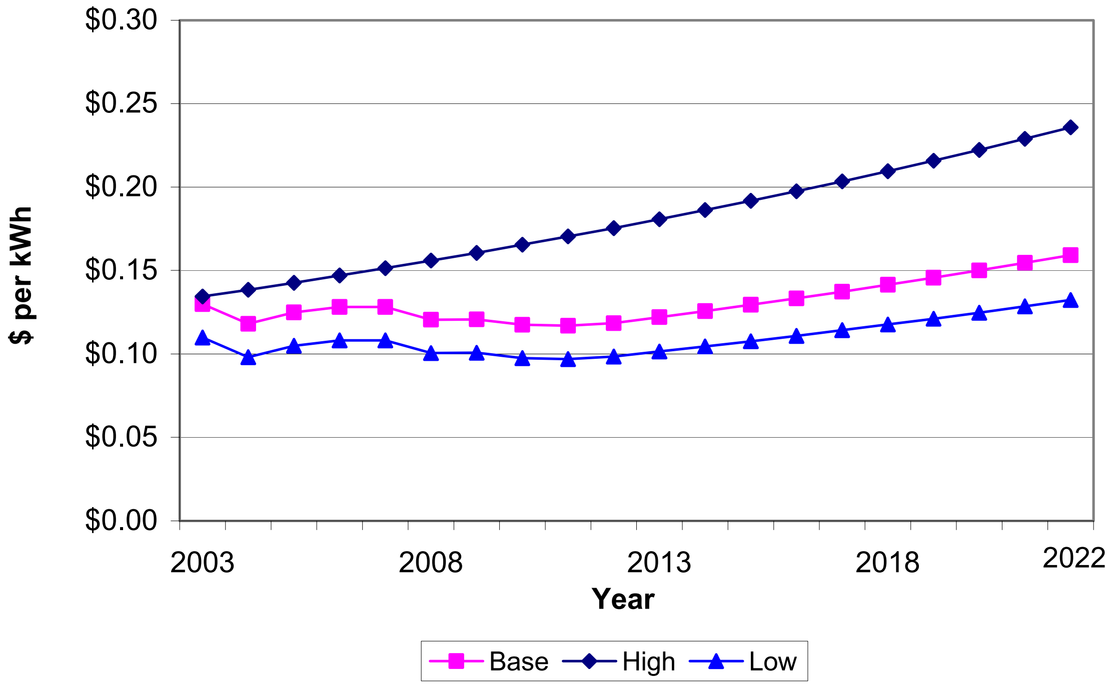

Figure 5-7
Residential Natural Gas Rates by Energy Cost Scenario

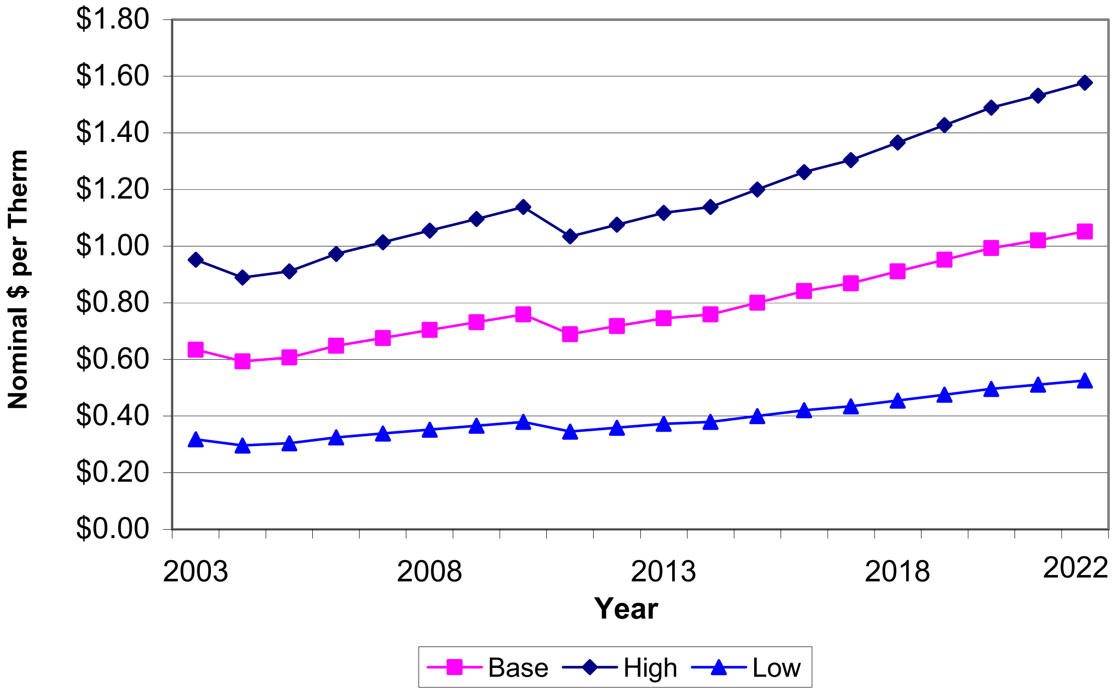

Table 5-3
Summary of Low and High Energy Cost Elements

		Energy Costs Element	
Fuel	**Cost Type**	**Low**	**High**
Electricity	Avoided Costs	50 percent lower than Base avoided costs.	25 percent higher than Base avoided costs.
	Residential Rates	2 cents per kWh below Base rates.	Current actual rates that persist, in real terms, throughout forecast period.
Natural Gas	Avoided Costs	50 percent lower than Base avoided costs.	50 percent higher than Base avoided costs.
	Residential Rates	50 percent lower than Base rates.	50 percent higher than Base rates.

The avoided-cost component of the Low energy cost element is fairly similar to the level of avoided costs that were in use prior to the energy crisis and, hence, are certainly a plausible bound on the low side. The rate component of the Low energy cost element is hypothetical by definition in that the rates are set at 1998 frozen values, putting them below what customers are actually experiencing. Nonetheless, the faster rates return to pre-crisis levels relative to our Base rate forecast, the more applicable the Low rate forecast element would become.

The High element was developed when the energy crisis was still in full force, that is, before wholesale electricity prices had stabilized and fallen. It was designed to capture the possibility that premium market prices (and by implication, supply shortages) were exacerbated and continued into the future. From today's vantage point, the High element seems unlikely, however, there are a number of high impact, low probability events that could occur in an energy future reflected by the High element.

5.2.2 Program Funding Elements

In this study, we constructed four different future funding level elements for the major IOUs' electric energy-efficiency programs for the residential existing construction market. In combination with the energy cost elements, the program funding elements are used to model achievable potential. Across all energy cost scenarios, the funding level elements are labeled simply Level 1, Level 2, Level 3, and Level 4. Total program funding expenditures increase sequentially from Level 1 to Level 4. Level 1, the lowest expenditure level, generally approximates spending levels in recent years. Level 4, the highest expenditure element, is used to generate our estimates of maximum achievable potential. As will be clarified further below, under the Base energy avoided costs, the funding levels are benchmarked to actual funding levels today so that Level 1 represents "Continued Current" levels of funding, Level 2 represents approximately a "50% Increase" above Level 1, Level 3 represents approximately a "100% Increase" over Level 1, and Level 4 represents the "Maximum Achievable" potential, which equates to roughly a 450 percent increase over Level 1 funding for electric scenarios and an approximately 300 percent increase for natural gas. These qualitative funding level scenario labels apply only under the Base energy costs; otherwise (under the Low and High avoided costs) the funding levels are described only with the Level 1 through Level 4 labels.

Components of Program Funding

The components of program funding that vary under each of the program funding level elements are:

- Total marketing expenditures
- The amount of incremental measure costs paid through incentives
- Total administration expenditures.

As described in Section 4.5, customers must be aware of efficiency measures and associated benefits in order to adopt those measures. In our model, program marketing expenditures are converted to increases in awareness. Thus, under higher levels of marketing expenditures, higher levels of awareness are achieved. We also describe in Section 4.6 how program-provided measure incentives lead to increased adoptions through increases in participants' benefit-cost ratios. The higher the percentage of measure costs paid by the program, the higher the participant benefit-cost ratio and number of measure adoptions. Purely administrative costs, though necessary and important to the program process, do not directly lead to adoptions; however, they must be included in the program funding level elements because they are an input to program benefit-cost tests.

Electricity Funding Levels

Level 1 Funding

For the Base energy cost scenario, our Level 1 funding was constructed to reflect the level of expenditures for the major IOUs' residential electric (existing construction) programs at different points in time over the 5 years preceding the 2001 energy crisis. To develop our Base Level 1 expenditure estimates, we reviewed actual expenditures reported in utility CPUC filings for nonresidential programs (excluding new construction).[4] Information on these expenditures is provided in Section 3.3. As shown in Table 5-4, over the period 1996 to 2000, reported expenditures for residential programs for the three electric utilities averaged roughly $68 million. In 2000, however, reported expenditures for residential programs were roughly $95 million.

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[4] These data were generally obtained from the major IOUs' Annual Earnings Assessment Proceeding Reports for the years 1996 through 2000. We also reviewed longer-term data compiled by the CPUC's Office of Ratepayer Advocates and the California Energy Commission, as well as a detailed file of forecast program expenditures by program type for PG&E for PY2002.

Table 5-4
Major IOU Residential Electric (Existing Construction) Expenditures and Savings, 1996 to 2000, Expenditures in 2002 $ millions, Savings in GWh)

Sector	Type	1996	1997	1998	1999	2000	Average
Total	Expenditures ($M)	$53	$44	$68	$80	$95	$68
	Savings (GWh)	160	144	161	181	361	201

We reviewed the same sources identified above to estimate program administration and marketing costs, as well as the IOUs' reported cost breakdowns in their PY2002 program proposals. Precise estimates of these costs are difficult to make from the sources available. We estimate that program expenditures made up roughly two-thirds of the total program costs, with financial incentives making up the rest. For our Level 1 funding, we set the initial-year program marketing and administration[5] expenditures at $42 million and split this amount evenly between marketing and administration (i.e., $21 million for administration and $21 million for marketing). Average program expenditures over the forecast horizon are summarized in Table 5-5.

The total incentives dollars are estimated directly in our model as a function of predicted adoptions. What we specify in the model is the percent of incremental measure cost paid by the program. The total incentives and average percent of incremental cost paid are shown in Table 5-5. The percent of incremental costs paid by measure is shown in Appendix J. We attempted to set these percentages as closely as possible to the utility incentive levels in recent years. We believe that the percent of measure costs paid in our Level 1 funding element, which average about 25 percent of measure costs, reasonably approximates actual program incentive levels over the historic comparison period.

In the Level 1 funding element, total marketing costs increase by inflation over the 10-year analysis period. We set administration costs to vary slightly over time as a function of program activity levels.[6] The percent of incremental measure costs paid over time is held constant.

Level 2 and Level 3 Funding

Level 2 and Level 3 represent increases in funding from Level 1. Funding levels were increased primarily by increasing both total marketing expenditures and per-unit incentive levels. Administration levels increase as noted above as a function of increases in program activity. We set the increases in marketing and incentive levels for Level 2 and Level 3 to result in roughly

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[5] Note that "administration", as used here, includes all non-incentive, non-marketing or awareness-building activities.

[6] We set changes in administration costs from year to year as a function of yearly changes in program savings. The function relates future year administration costs (AC_t) to the first-year administration cost (AC_1) as a function of future year program savings (kWh_x) and first-year program savings (kWh_1) as follows: $AC_t = 0.25 \times AC_1 + 0.75 \times kWh_t/kWh_1 \times AC_1$ with adjustments for inflation. Thus, we set 75 percent of future administration costs to be proportional to first-year program savings; the remaining 25 percent is considered a fixed administrative cost that would be required even with very small programs.

50-percent and 100-percent increases in total program expenditures when modeled with the Base energy costs. As shown in Table 5-5, marketing costs average $24 million per year for Level 2 and $26 million per year for Level 3. The average fraction of incremental costs paid for by incentives increases from roughly one-quarter in Level 1 to just over half in Level 3.

Level 4 Funding (Maximum Achievable)

The Level 4 funding level is used to estimate maximum achievable potential. The key characteristic of this funding level is that 100 percent of incremental measure costs is paid for by the program. In addition, marketing costs increase to an average of $36 million per year.

Table 5-5
Summary of Forecasted Residential Electric Program Expenditures by Scenario
(Average Expenditures Over the 10-Year Analysis Period in Millions of $ per Year)

	Cost Components				
Scenario Energy Cost – Funding Level	**Marketing**	**Administration**	**Incentives**	**Total**	**Average % of Measure Cost Paid***
Base – "Continued Current" (L1)	$21	$24	$21	$66	25%
Base – "50% Increase" (L2)	$24	$38	$50	$111	40%
Base – "100% Increase" (L3)	$26	$51	$99	$177	55%
Base – "Max Achievable" (L4)	$36	$50	$231	$317	100%
Low – L1	$21	$15	$10	$47	25%
Low – L2	$24	$27	$29	$80	40%
Low – L3	$26	$45	$74	$145	55%
Low – L4	$36	$47	$115	$198	100%
High – L1	$21	$31	$31	$83	25%
High – L2	$24	$44	$66	$134	40%
High – L3	$26	$53	$111	$190	55%
High – L4	$36	$48	$235	$320	100%

*Over the first several years of the forecast period, the percent of measure cost paid under funding Levels 2 through 4 are ramped up from the 25 percent of measure costs paid under Level 1 funding.

Natural Gas Funding Levels

Level 1 Funding

For the Base energy cost scenario, our Level 1 funding was constructed to try to reflect the level of expenditures for the major IOUs' residential natural gas (existing construction) programs for the most recent 5 years for which data were readily available. To develop our Base Level 1 expenditure estimates, we used actual IOU residential natural gas expenditures tracked by the

CEC for the period 1995 to 1999 (the last year available in the spreadsheet received from the CEC). Information on these expenditures is provided in Section 3. As shown in Table 5-6, over the period 1995 to 1999, reported expenditures for residential programs for the three utilities averaged roughly $42 million, while savings averaged 6,224 million therms. As discussed in Section 3, direct assistance programs targeting low-income customers accounted for roughly 80 percent of residential natural gas program expenditures, but only make up roughly 30 percent of program savings impacts.

Table 5-6
Major IOU Residential Natural Gas (Existing Construction) Expenditures and Savings, 1995 to 1999, Expenditures in 2002 $ millions, Savings in Millions of Therms

Sector	Type	1995	1996	1997	1998	1999	Average
Total	Expenditures	$39	$42	$43	$42	$42	$42
	Savings	5,354	5,554	5,306	8,499	6,408	6,224

We reviewed the same sources identified above to estimate program administration and marketing costs, as well as the IOUs' reported cost breakdowns in their PY2002 program proposals. Similar to electricity, precise estimates of these costs are difficult to make from the sources available. We estimate that program expenditures made up roughly 90 percent of the total program costs, with financial incentives making up the rest. As shown in Table 5-7, for our Level 1 funding, we set the initial-year program marketing and administration expenditures at $24 million and split this amount 75 percent/25 percent between marketing and administration (i.e., $18 million for marketing and $6 million for administration).

The total incentives dollars are estimated directly in our model as a function of predicted adoptions. What we specify in the model is the percent of incremental measure cost paid by the program. The total incentives and average percent of incremental cost paid are shown in Table 5-7. The percent of incremental costs paid by measure is shown in Appendix J. We attempted to set these percentages as closely as possible to the utility incentive levels in recent years. We believe that the percent of measure costs paid in our Level 1 funding element, which average about 25 percent of measure costs, reasonably approximates actual program incentive levels over the historic comparison period.

In the Level 1 funding element, total marketing costs increase by inflation over the 10-year analysis period. We set administration costs to vary slightly over time as a function of program activity levels.[7] The percent of incremental measure costs paid over time is held constant.

Level 2 and Level 3 Funding

Level 2 and Level 3 represent increases in funding from Level 1. Funding levels were increased primarily by increasing both total marketing expenditures and per-unit incentive levels. Administration levels increase, as noted above, as a function of increases in program activity.

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[7] We set changes in administration costs for natural gas using the same formula as described for electricity above.

We set the increases in marketing and incentive levels for Level 2 and Level 3 to result in roughly 50-percent and 100-percent increases in total program expenditures when modeled with the Base energy costs. As shown in Table 5-7, marketing costs average $23 million per year for Level 2 and $25 million per year for Level 3. The average fraction of incremental costs paid for by incentives increases from roughly one-quarter in Level 1 to just over half in Level 3.

Level 4 Funding (Maximum Achievable)

The Level 4 funding level is used to estimate maximum achievable potential. The key characteristic of this funding level is that 100 percent of incremental measure costs is paid for by the program. In addition, marketing costs increase to an average of $29 million per year.

Table 5-7
Summary of Forecasted Residential Natural Gas Program Expenditures by Scenario (Average Expenditures Over the 10-Year Analysis Period in Millions of $ per Year)

	Cost Components				
Scenario ***Energy Cost – Funding Level***	**Marketing**	**Administration**	**Incentives**	**Total**	**Average % of Measure Cost Paid***
Base – “Continued Current” (L1)	18	6	3	27	25%
Base – “50% Increase” (L2)	23	9	5	37	40%
Base – “100% Increase” (L3)	25	12	10	48	55%
Base – “Max Achievable” (L4)	29	15	37	80	100%
Low – L1	18	3	1	22	25%
Low – L2	23	3	1	27	40%
Low – L3	25	7	3	35	55%
Low – L4	29	14	16	59	100%
High – L1	18	10	7	35	25%
High – L2	23	11	12	45	40%
High – L3	25	17	21	63	55%
High – L4	29	18	67	113	100%

*Over the first several years of the forecast period, the percent of measure cost paid under funding Levels 2 through 4 are ramped up from the 25 percent of measure costs paid under Level 1 funding.

5.2.3 Combining the Energy Cost and Funding Level Elements into Scenarios

Combining the energy cost and program funding elements produces the 12 scenarios under which we estimate achievable potential in this study. Table 5-1 shows the combinations.

As when we presented the actual expenditures for each scenario, the energy cost and program funding elements are interactive in two important respects:

1. Only measures that are economic, as defined in Section 4.5, enter into the achievable potential analyses
2. Adoption levels for individual measures will vary across energy cost scenarios because of differences in residential rates.

Whether a measure is economic depends on whether its Total Resource Cost (TRC) test is greater than 1.0. Measure-level TRC ratios vary under the different energy cost elements because of differences in avoided costs between the Low, Base, and High elements. As a result, scenarios associated with the Low energy cost element have the fewest number of measures included in the achievable potential analyses, while scenarios associated with the High energy cost element have the greatest number of measures included in the achievable potential analyses.

With respect to the second point above, adoption levels for individual measures (both naturally occurring and program induced) will vary across energy cost elements even when measure-level incentives are identical because the differences in residential rates will result in different participant benefit-cost ratios (because adoption levels are a direct function of participant benefit-cost as discussed in Section 4.6).

Both of the interactions identified above are intuitively correct and reflect what we have seen throughout the history of efficiency programs in California. When avoided costs are low, incentives are available for fewer measures than when avoided costs are high. Similarly, customer adoption of measures is lower when rates are low than when they are high.

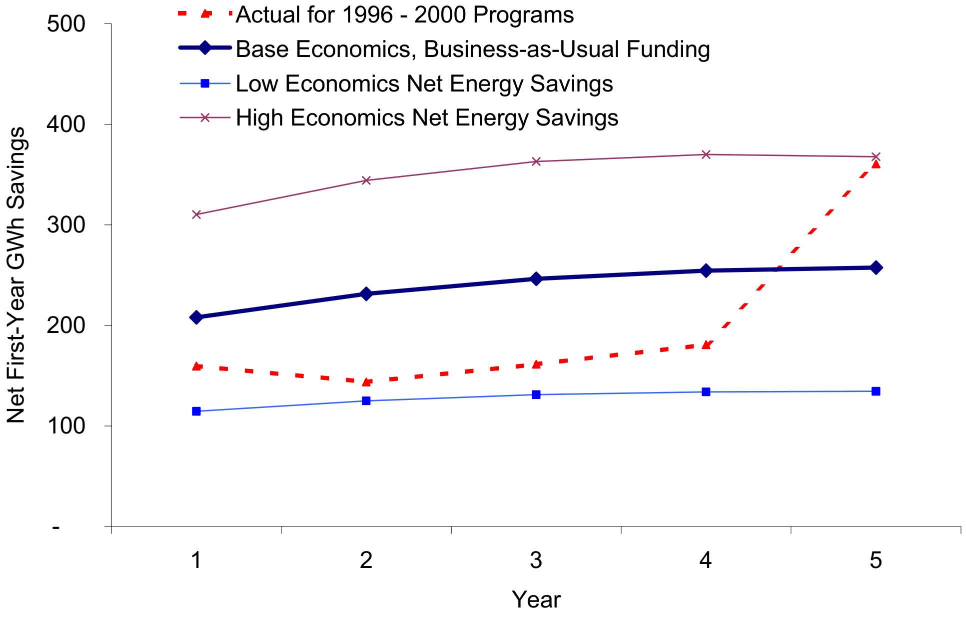
As a result of these interactions, total program funding levels will vary across energy cost elements even when the amount of total market expenditures and the percent of individual measure costs paid for by incentives are the same.

5.3 RESIDENTIAL ACHIEVABLE POTENTIAL SCENARIO CALIBRATION

We used the major IOUs' reported residential sector electric energy savings accomplishments from 1996 to 2000 as the base for our calibration of our achievable electric potential estimates. We compared the 1996 to 2000 actual program savings to the first 5 years of our forecasted savings. As shown in Table 5-4, residential sector electric savings range from 140 to 360 GWh per year over this period and averaged roughly 200 GWh. Average annual residential sector funding over this period was $68 million.

The two scenarios that are closest to the market and program funding conditions of the 1996 to 2000 period are scenarios *Base – “Continued Current” (Level 1)* and *Low – Level 1*. Average annual funding for these scenarios for the first 5 years of our analysis is $64 and $53 million, respectively. We picked these two scenarios for model calibration because the economic conditions for the 1996 to 1999 period were similar to those incorporated in the Low economic scenarios, while the economic conditions in 2000 were closer to the assumed economic conditions in the Base and High scenarios. Given this and the concomitant funding levels, one would expect the *Base* and *Low – Level 1* scenario energy savings to bound the actual energy savings during the 1996 to 1999 period, while the *Base* and *High Level 1* savings should bound the 2000 results. As shown in Figure 5-8, our calibrated results bound the actual as expected.

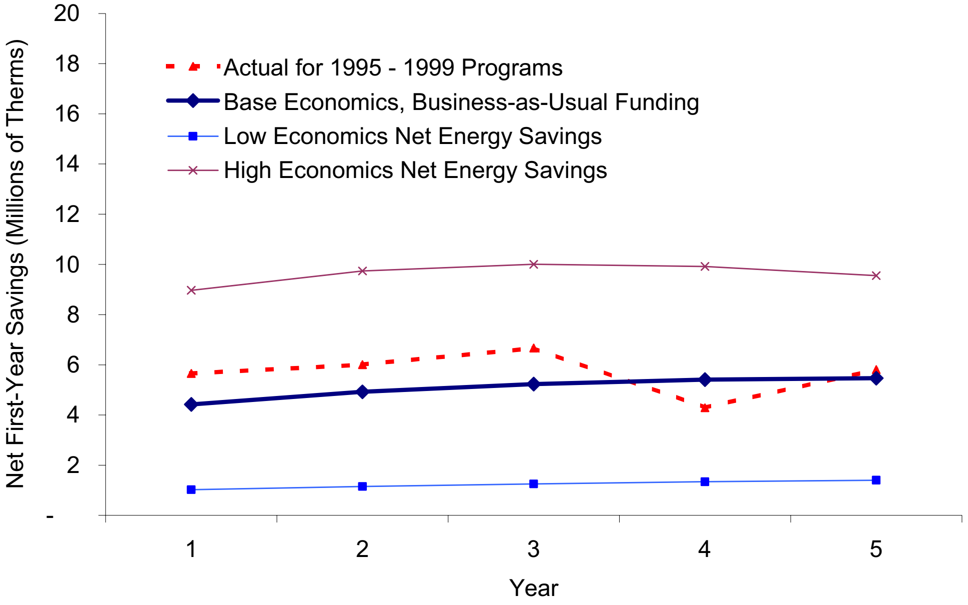
Figure 5-8
Residential Electric Achievable Potential Estimates versus Actuals



We used the major IOUs' reported residential sector natural gas savings accomplishments from 1996 to 2000 as the base for our calibration of our achievable electric potential estimates. We compared the 1995 to 1999 actual program savings to the first 5 years of our forecasted savings. As shown in Table 5-6, residential sector natural gas savings range from 5.3 to 8.5 Mth per year over this period and averaged roughly 6.2 Mth. Average annual residential sector funding over this period was $42 million.

We utilized the *Base – "Continued Current" (Level 1)* scenario for model calibration. Program funding levels in this scenario are lower than those seen in the 1995-1999 period, but projected gas costs are high (making more measures cost effective). As shown in Figure 5-9, our base calibrated results are reasonably close to actual impacts. High and low economic scenario results bound the actual.

Figure 5-9
Residential Natural Gas Achievable Potential Estimates versus Actuals



6

ELECTRIC TECHNICAL AND ECONOMIC POTENTIAL RESULTS

This section presents our estimates of electric technical and economic energy-efficiency potential for the existing construction portion of the residential sector of the major investor-owned utility (IOU) service territories. Technical energy savings potential is estimated to be roughly 19,700 GWh, and economic potential is estimated to be about 15,000 GWh. Technical demand savings potential is estimated to be over 5,500 MW, while economic potential is estimated to be approximately 3,500 MW.

6.1 INTRODUCTION

A total of 59 residential electric measures were included in the analyses. The complete set of measures considered was pre-screened to only include those measures that are presently commercially available to provide a realistic assessment of potential. Thus, few emerging technologies were included in the analysis. The measure analysis was segmented into three residential building types (single family, multi-family, and mobile homes) for each of the three electric IOU service territories. For weather-sensitive measures, we further segment by two building vintages (pre-1998 and pos-1979) and the 10 California Energy Commission (CEC) forecasting climate zones covering the major IOUs. As a result, our analyses were conducted for approximately 2,400 measure-market segment applications.

The technical and economic potential results are presented in several formats:

- In aggregate for each utility
- By end-use and measure
- In the form of energy and demand supply curves.

We provide estimates of savings in both absolute and percentage terms. We express percent savings in two ways: 1) percent of total residential energy or demand for the State; and 2) percent of energy or demand addressed in this study, which only includes energy use for selected measures in the territories of the three major IOUs. In both cases, we use the CEC's end-use forecast data for the year 2000.[1] Total base energy is the CEC's estimate of the amount of energy consumed for all end uses and building types in the residential sector for the IOUs in 2000.

For electric consumption, the total base electric use estimated for 2000 in the major IOUs is roughly 71,000 GWh. We estimate that the peak demand associated with total residential energy for the three utilities is approximately 15,700 MW. Energy-efficiency measures are analyzed for the most important end uses, but not all end uses. In particular, we have not included measures

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[1] California Energy Demand, 2000 – 2010, CEC, P200-00-02, June. The CEC provided data on square footage, end-use saturation, and end-use intensity to support this study.

for cooking or for electric miscellaneous end uses, such as televisions, radios, computers, and waterbeds. As shown in Figure 2-9, the cooking end use comprises about 5 percent of residential energy use and miscellaneous/other end uses comprise about 12 percent of residential energy use. As a result, the end uses for which we do apply efficiency measures account for about 83 percent, or roughly 59,000 GWh of energy use. Our corresponding estimate of peak demand for the studied end uses is about 13,800 MW, which makes up 92 percent of peak demand for the residential sector. We refer to these estimates as the base energy use and peak demand addressed.

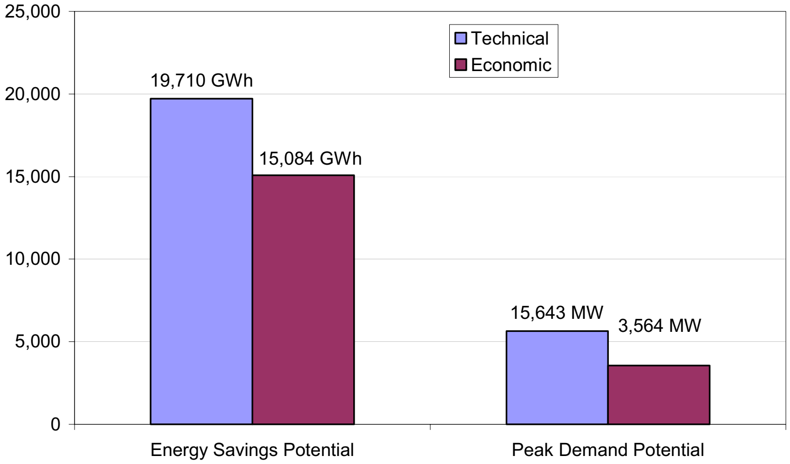
6.2 ELECTRIC TECHNICAL AND ECONOMIC POTENTIAL UNDER BASE ENERGY COSTS

This subsection presents residential technical and economic potential estimates for electric savings under the base energy costs described in Section 5. Economic potential under the alternative Low and High energy costs is presented in Section 6.3.

6.2.1 Aggregate Electric Technical and Economic Savings Potential by Utility

In Figure 6-1, we present our estimates of total electric technical and economic potential for energy and peak demand.

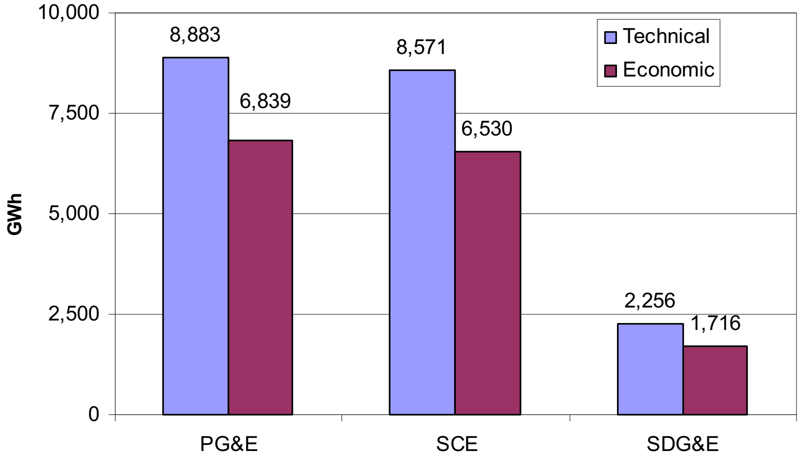
Figure 6-1
Estimated Electric Technical and Economic Potential
(Residential Sector Existing Construction, PG&E/SCE/SDG&E)



Figures 6-2 and 6-3 show technical and economic potential by utility. Overall, technical energy savings potential is estimated to be roughly 19,700 GWh, about 28 percent of total residential electric usage (i.e., 19,710 GWh Savings ÷ 70,595 GWh of base consumption) and 32 percent of the base energy addressed (i.e., 19,710 ÷ 62,124). Economic potential is estimated to be about 15,000 GWh, about 21 percent of total base usage and 26 percent of the base energy addressed. Technical demand savings potential is estimated to be over 5,500 MW, about 36 percent of total peak demand, which represents 41 percent of the base peak demand addressed. Economic potential is estimated to be approximately 3,500 MW, about 23 percent of total base demand (26 percent of base demand addressed).

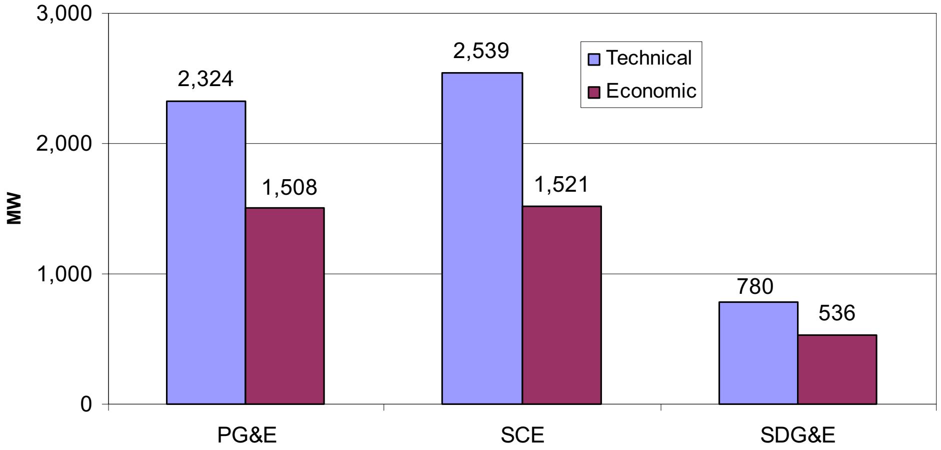
The potentials in the Pacific Gas and Electric (PG&E) and Southern California Edison (SCE) territories are very close in size. PG&E has slightly higher economic savings potential at about 6,800 GWh, followed closely by SCE's potential of approximately 6,500 GWh. As a percent of base consumption, the technical and economic energy savings potentials are 31 percent for San Diego Gas & Electric (SDG&E), 29 percent for SCE and 26 percent for PG&E. Differences are due to a number of factors such as climate, end-use saturations, and the current penetration of energy-efficiency technologies.

Figure 6-2
Residential Electric Savings Potential by Utility



We estimate technical peak demand savings potential of over 2,000 MW for both PG&E and SCE and just under 800 MW for SDG&E. PG&E and SCE each have economic peak demand savings potential of approximately 1,500 MW, while our estimate for SDG&E is approximately 500 MW. We estimate that SDG&E has a slightly higher relative percentage of demand savings potential at 24 percent, while estimates of demand savings potential for PG&E and SCE are 20 and 22 percent, respectively.

Figure 6-3
Residential Electric Demand Savings Potential by Utility



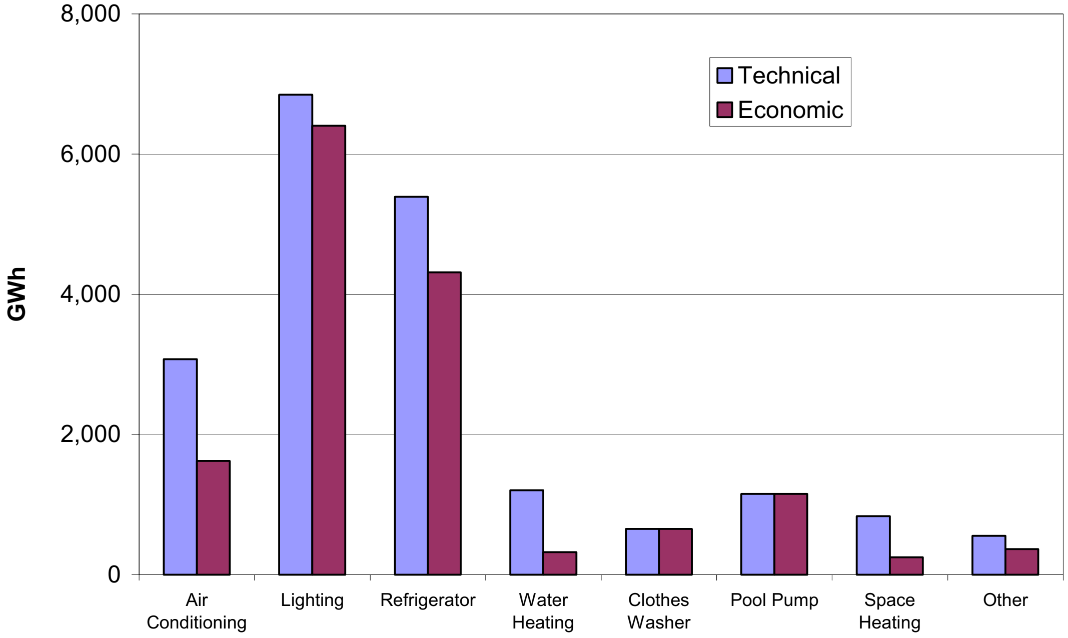
6.2.2 Electric Technical and Economic Savings Potential by End Use & Measure

Estimates of energy and peak demand savings potential are provided by end use in Figures 6-4 through 6-7. The first of the figures provides savings in absolute terms; the second, in terms of the percentage of base case end-use energy or peak demand. Lighting represents the largest end-use savings potential, followed by refrigerators (principally early replacement), in absolute terms for energy.

As expected, air conditioning potential represents the largest portion of the technical peak demand savings potential by far, followed by lighting and refrigerator peak demand savings potential. While the economic savings potential is approximately half of the technical potential for air conditioning, the technical and economic potential savings is virtually identical for clothes washers and pool pumps because these end uses are comprised of single measures that have been estimated to be cost effective. While relatively low in terms of absolute savings, the savings potential of clothes washers and pool pumps each represent approximately 40 percent of base end-use consumption and peak demand.

Economic savings potential values are summarized by end use and utility in Table 6-1. In addition to presenting the end uses discussed above, the table presents the component end uses in the other category: clothes dryers, dishwashers, and freezers.

Figure 6-4
Residential Electric Savings Potential by End Use



Note: refrigerator savings are primarily from early replacement of older units.

Figure 6-5
Residential Electric Savings Potential as Percent of Base End-Use Consumption

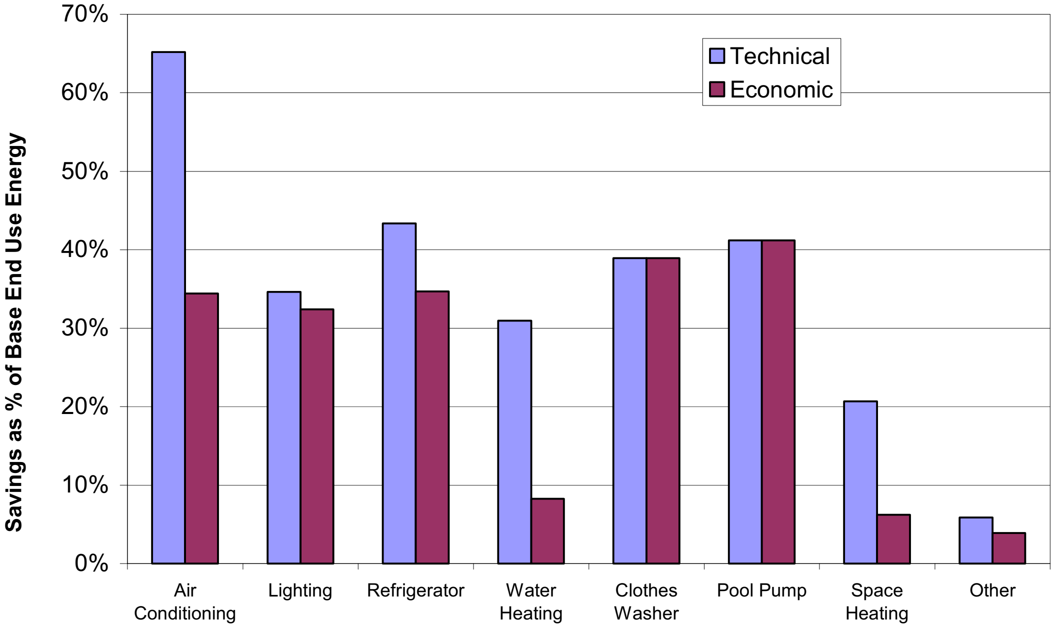


Figure 6-6
Residential Electric Demand Savings Potential by End Use

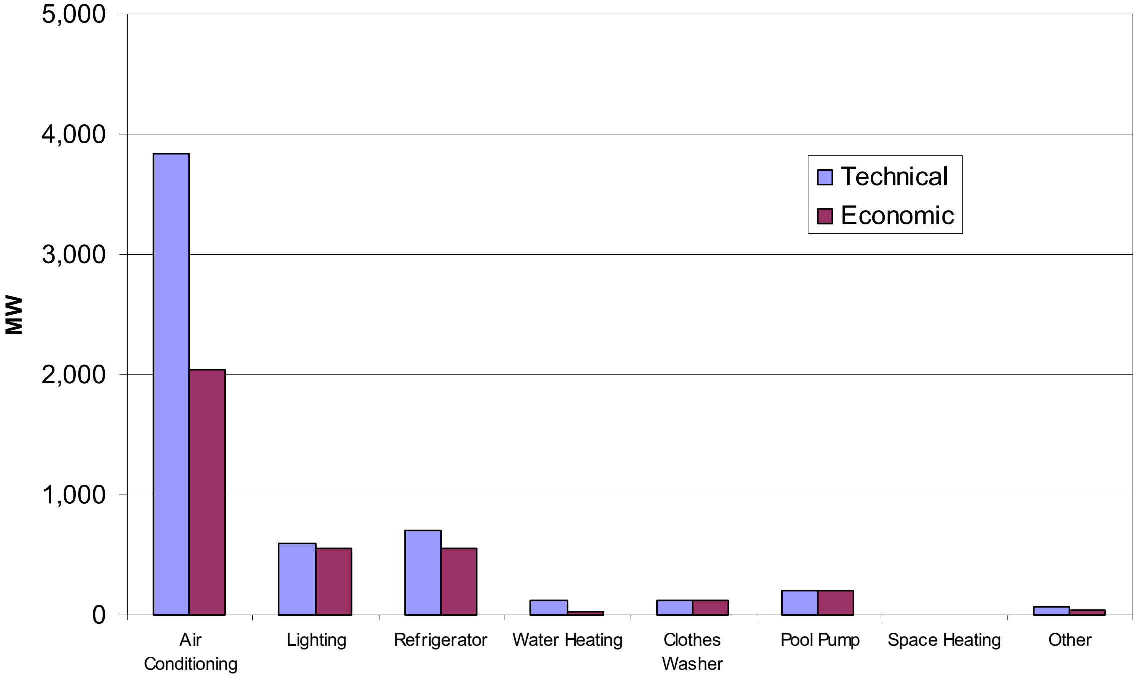


Figure 6-7
Residential Electric Savings Potential as Percent of Base End-Use Peak Demand

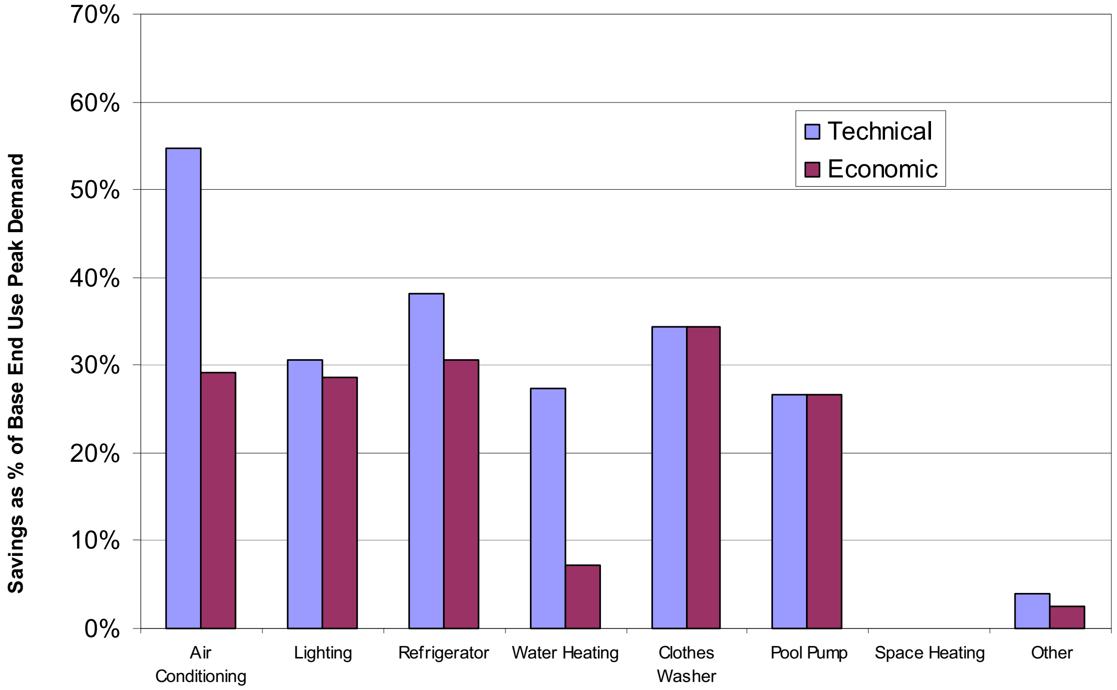
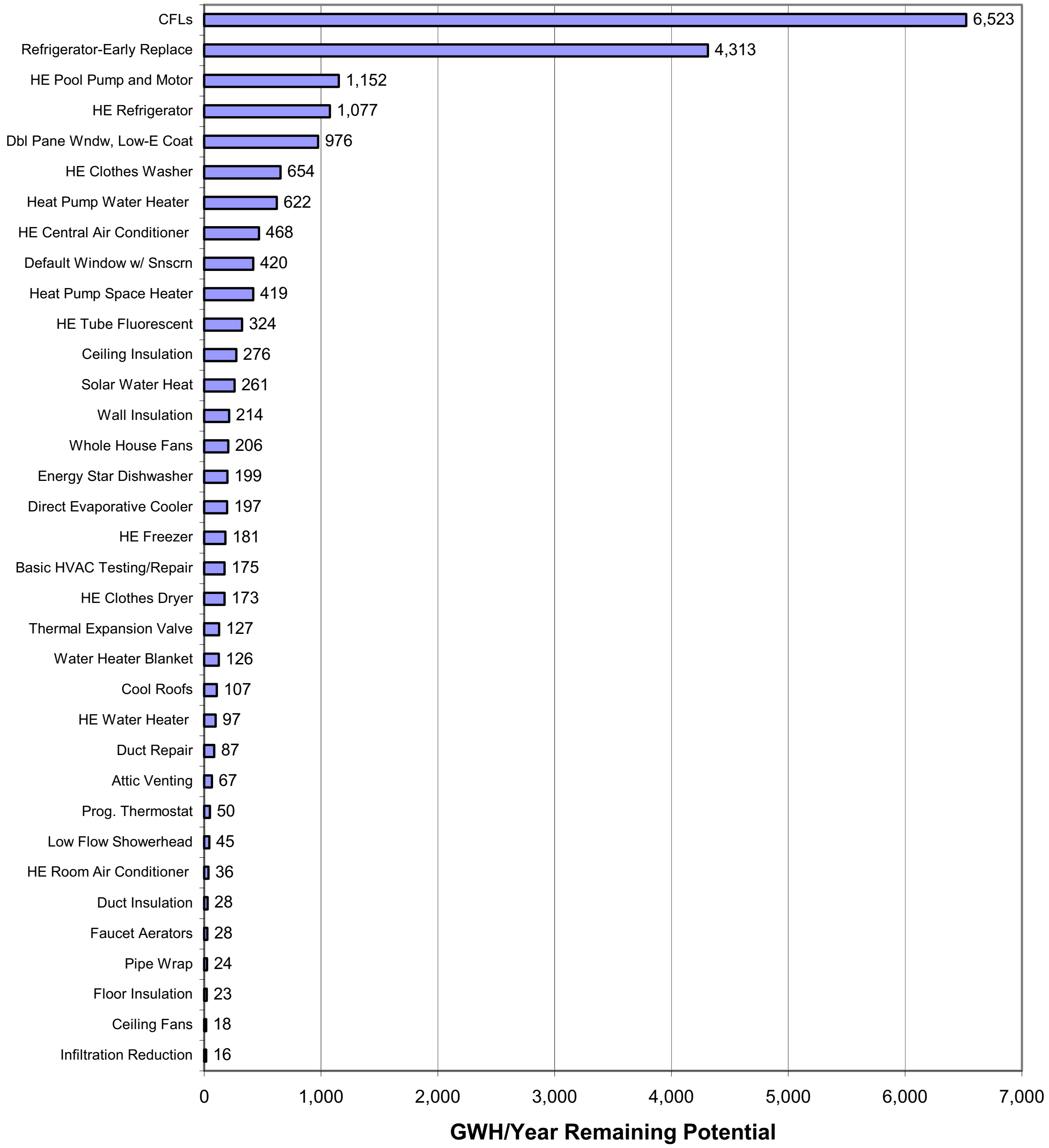


Table 6-1
Residential Electric Economic Savings Potential by End Use and Utility

	PG&E		SCE		SDG&E		Total	
End Use	GWh	MW	GWh	MW	GWh	MW	GWh	MW
Air Conditioning	737	833	695	854	191	358	1,623	2,045
Clothes Dryer	29	4	18	3	5	1	52	8
Clothes Washer	317	58	257	47	79	15	653	120
Dishwasher	77	7	40	3	15	1	132	11
Freezer	90	12	71	10	20	3	181	25
Lighting	2,970	259	2,732	239	701	61	6,403	559
Pool Pump	380	68	584	104	189	34	1,153	206
Refrigerator	1,946	253	1,908	248	459	60	4,313	561
Space Heater	148	0	87	0	16	0	251	0
Water Heater	144	14	138	13	39	4	321	31
Total Economic Potential	**6,838**	**1,508**	**6,530**	**1,521**	**1,714**	**537**	**15,082**	**3,566**
Total Electricity Use	34,044	7,724	29,508	6,738	7,042	1,240	70,595	15,701

Figures 6-8 and 6-9 present estimates of technical potential by measure for energy and peak demand, respectively. In terms of energy savings, CFLs represent a third of the potential for residential electric savings. Early replacement of refrigerators has the second greatest energy savings potential at 22 percent. The remaining 33 measures account for 45 percent of technical potential; most of these measures represent less than 3 percent each of total technical potential.

Figure 6-8
Residential Electric Savings Technical Potential by Measure



For peak demand savings, the relative order of measures shifts substantially, causing measures that affect the use of air conditioning to increase in importance. Double-pane windows with low-E coating represent the largest demand savings opportunity at 23 percent. High-efficiency central air conditioning, CFLs, early replacement of refrigerators, and the default window with sunscreen represent 10 percent each of additional demand savings potential. The remaining 30 measures each represent 5 percent or less demand savings potential. Table 6-2 provides a summary of issues and observations associated with these results.

Figure 6-9
Residential Electric Demand Savings Technical Potential by Measure

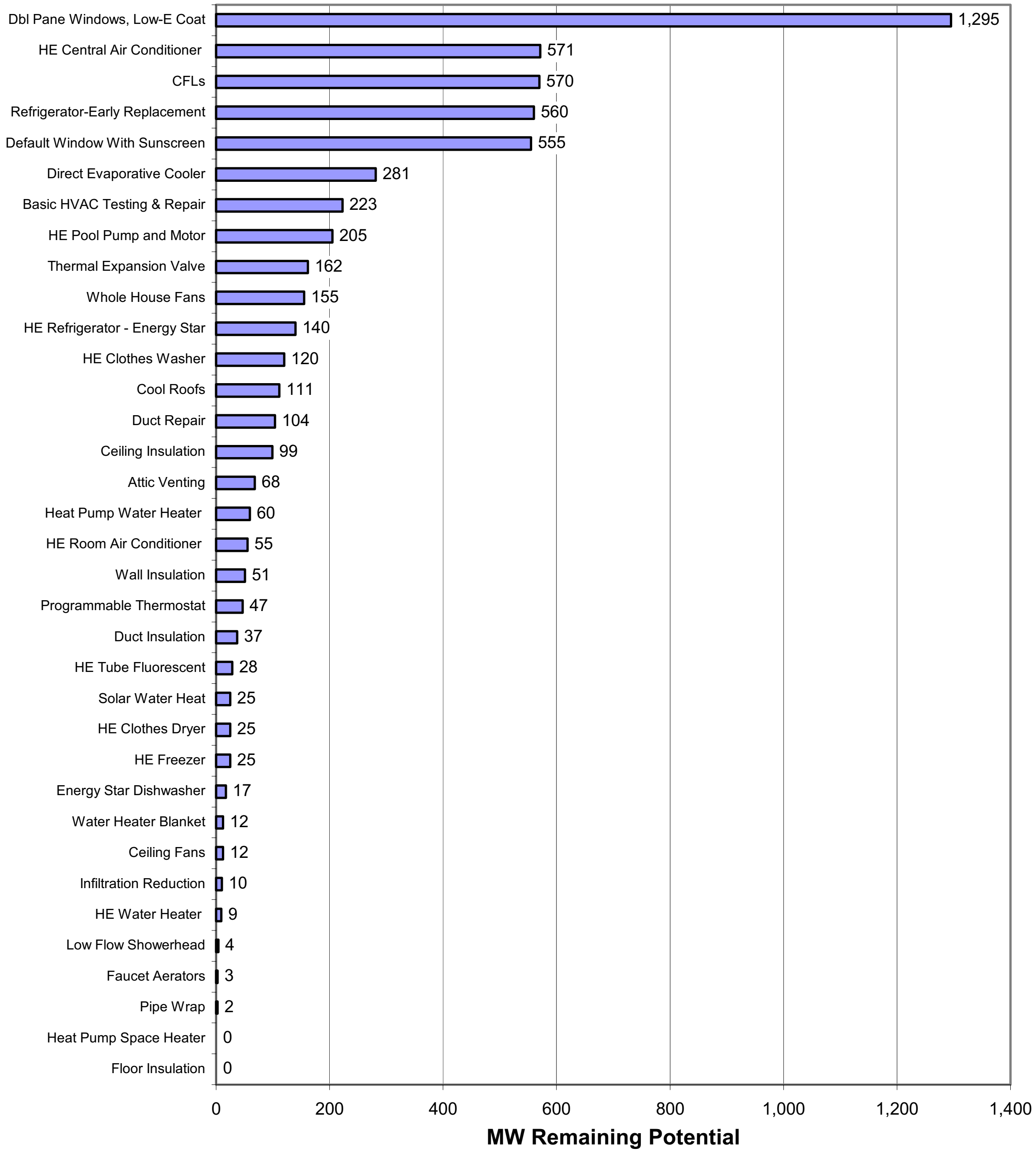


Table 6-2
Considerations for Interpreting Results for Residential Electric Potential

End Use	Key Considerations
Space Cooling	1) ***Standards***. Because of current standards, the minimum efficiencies of new air conditioning units are usually higher that the efficiencies of units they replace. Because our ultimate goal in this study is to estimate program savings potential, these improvements have been netted out of our base-case energy and demand and are not included in our potential estimates. We estimate that the current air conditioner standards would ultimately result in about 300 GWh of savings as the stock of existing air conditioners is replaced with new standard-efficiency units. Including these savings in our potential estimates would have increased our cooling technical potential by about 20 percent. On the other hand, new central air conditioner efficiency standards (increasing minimum efficiencies from 10 SEER to 12 SEER) are set to take effect in 2006. These new standards, which will lower potential program savings beginning in 2006, have not been factored into our estimates. 2) ***Behavior-related measures***. Two of the cooling measures we addressed, programmable thermostats and ceiling fans, have a behavioral component that interjects additional uncertainty into the calculation of measure savings. To be effective, customers must use these measures in a way the reduces air conditioner usage – setting the thermostat to reduce air conditioner run time and utilizing ceiling fans in lieu of air conditioning during temperate periods. We have chosen modest savings estimates of 5 percent for these measures. 3) ***Thermal Expansion Valves (TXVs)***. This measure has not been included, historically, in utility retrofit programs. While cooling savings of 10 to 20 percent appear possible at a relatively low cost (a few dollars for equipment plus installation costs), there is little information available on customer acceptance of this measure and verified in situ savings results. TXVs are included in this study, utilizing a 10-percent savings factor, but we acknowledge uncertainty in our savings potential estimates. 4) ***Windows***. Double-pane windows with low-E coating are included in this study as a cost-effective measure. Recent evidence has indicated that these windows may soon be considered standard equipment, and associated savings may not be available for programs.
Lighting	1) ***CFL feasibility***. Much of the savings potential for lighting is tied to the installation of CFLs. A key factor affecting the CFL market is the feasibility of installing the larger CFL bulbs in fixtures traditionally designed for incandescent bulbs. For this study, we have capped the CFL feasibility factor at 66 percent of incandescent-type fixtures, but true feasibility may be lower or higher.
Refrigeration	1) ***High-efficiency refrigerators***. Given the recent increase in refrigerator efficiency standards (in 2001), there is limited availability of ENERGY STAR-qualifying refrigerators. Thus, establishing reasonable high-efficiency refrigerator costs and companion savings estimates for this study has been problematic. We have assumed a 10 percent savings factor for an incremental cost of $100. 2) ***Refrigerator early replacement***. Large portions of our overall savings potential estimates are tied to the early replacement of working refrigerators with new, standard-efficiency refrigerators. Savings result because new units are generally more efficient than older units. For this measure, we've assumed a 6-year acceleration in refrigerator purchases and limited applicability to units that are 10-years old or older. Technical and economic potential for this measure will decrease fairly rapidly as the older refrigerators are replaced naturally.

6.2.3 Electric Energy-Efficiency Supply Curves

Our residential sector energy-efficiency supply curves are shown in Figures 6-10 and 6-11 for energy and peak demand savings potential, respectively. The curves are shown in terms of savings as a percentage of total residential sector energy consumption and peak demand for the three utilities in scope. Note that our economic potential figures presented previously are based on the Total Resource Cost test as described in Section 4. Also note that our avoided-cost values include both energy and demand benefits. Thus, our economic potential integrates the value of the savings potentials shown in both the energy and demand supply curve figures.

Table 6-3 shows aggregated energy supply curve values by measure. These results are aggregated across household type and utilities. Individual segment results can vary significantly from the aggregated average values shown. Detailed economic results for individual measures by market segment are provided in Appendix F, though the results in this appendix are not additive. Readers should note that the figures aggregate three CFL measures that vary by hours per use each day. The 6.0 and 2.5 hr/day CFLs, represent 2,138 and 3,941 GWh potential savings respectively, and both have a levelized energy cost of $0.03/kWh, while the 0.5 hr/day CFLs are much less attractive, representing 443 GWh potential savings with a levelized energy cost of $0.09/kWh. Consistent with CPUC program guidelines for PY2002 (CPUC 2001), an 8.15-percent discount rate was used in the analysis.

Figure 6-10
Residential Electric Energy-Efficiency Supply Curve – Energy

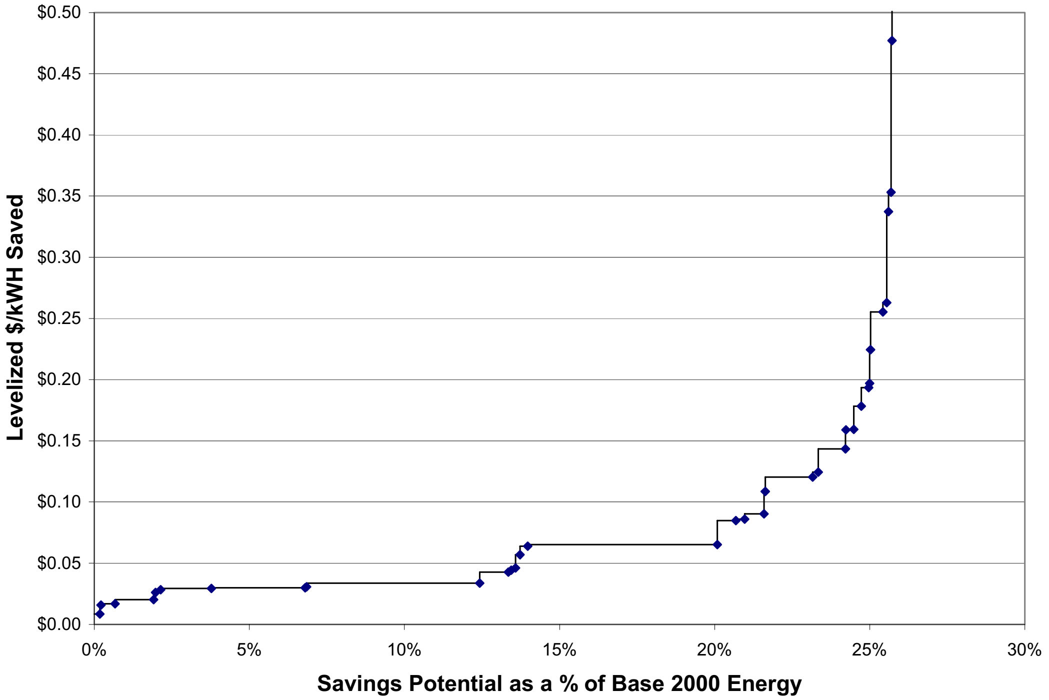
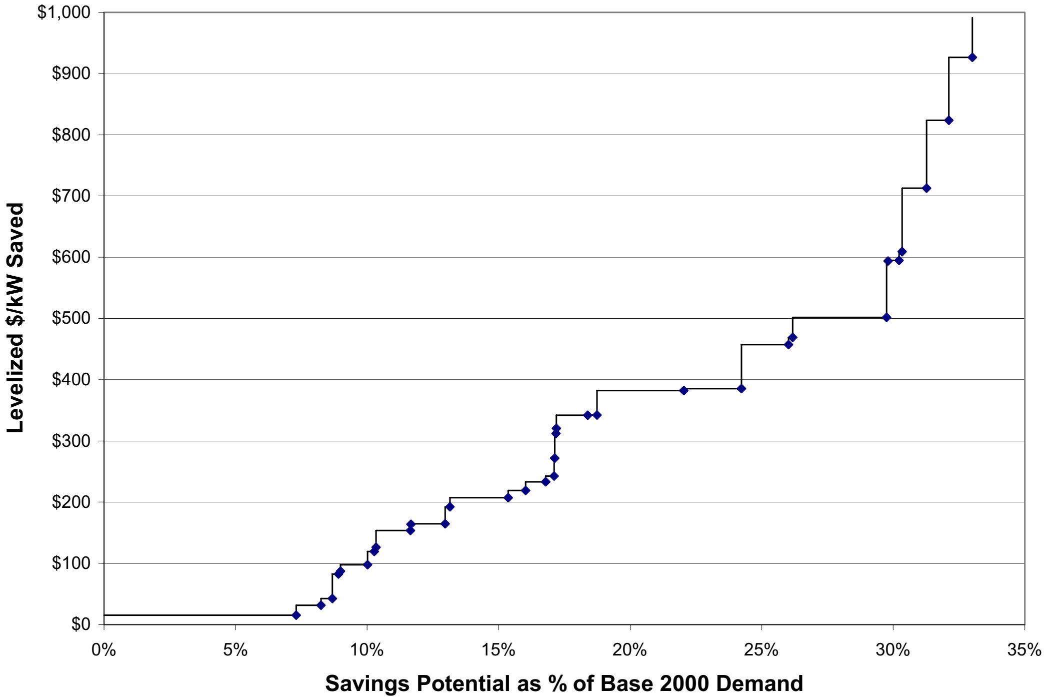


Figure 6-11
Residential Electric Energy-Efficiency Supply Curve – Demand



6.2.4 Technical Potential for Refrigerator Recycling and Evaporative Coolers

Second refrigerator recycling and evaporative cooler measures were not included in our potential analysis. This is because both measures involve a reduction in customer utility that is not easily valued for integration into our cost-effectiveness and market-penetration analyses. With refrigerator recycling, measure impacts are tied to customers giving up the use of their second refrigerator. With evaporative coolers, customers must utilize what some consider a lower quality type of cooling.

While we did not develop an economic analysis for the refrigerator and evaporative cooler measures, we assessed their technical savings potential to provide an indication of possible savings from measure implementation:

- For the second refrigerator measure, we assessed the impacts of removing all non-primary refrigerators from all homes in the IOU service areas.
- For the evaporative cooler measure, we assessed the impacts of converting all residential air conditioners in the IOU service areas to evaporative coolers.

Table 6-3
Aggregated Measure Values for Electric Energy-Efficiency Supply Curves

Measures	GWH Savings	Cum. GWH Savings	Levelized Energy Cost $/kWH	Cum. Percent Savings
Water Heater Blanket	126	126	$ 0.008	0%
Pipe Wrap	24	150	$ 0.016	0%
HE Tube Fluorescent	324	475	$ 0.017	1%
Dbl Pane Wndw, Low-E	976	1,450	$ 0.023	2%
Low Flow Showerhead	45	1,495	$ 0.026	2%
HE Pool Pump and Motor	1,152	2,648	$ 0.029	4%
Faucet Aerators	28	2,676	$ 0.031	4%
CFLs	6,523	9,199	$ 0.036	13%
HE Clothes Washer	654	9,852	$ 0.043	14%
HE Water Heater	97	9,949	$ 0.057	14%
HE Freezer	181	10,131	$ 0.064	14%
Refrigerator-Early Replace	4,313	14,444	$ 0.065	20%
Heat Pump Space Heater	419	14,864	$ 0.085	21%
Energy Star Dishwasher	199	15,063	$ 0.086	21%
Duct Insulation	28	15,091	$ 0.109	21%
HE Refrigerator	1,077	16,169	$ 0.120	23%
Thermal Expansion Valve	127	16,295	$ 0.124	23%
Heat Pump Water Heater	622	16,917	$ 0.143	24%
HE Clothes Dryer	173	17,090	$ 0.178	24%
Wall Insulation	214	17,305	$ 0.205	25%
Ceiling Insulation	276	17,580	$ 0.214	25%
Prog. Thermostat	50	17,630	$ 0.240	25%
Basic HVAC Testing/Repair	175	17,806	$ 0.241	25%
Duct Repair	87	17,892	$ 0.263	25%
Floor Insulation	23	17,915	$ 0.477	25%
HE Room Air Conditioner	36	17,951	$ 0.529	25%
Default Window w/ Snscrn	420	18,370	$ 0.600	26%
Solar Water Heat	261	18,631	$ 0.647	26%
Direct Evaporative Cooler	197	18,829	$ 0.652	27%
Whole House Fans	206	19,034	$ 0.679	27%
Attic Venting	67	19,101	$ 0.789	27%
Central Air Conditioner	468	19,569	$ 1.095	28%
Infiltration Reduction	16	19,585	$ 2.049	28%
Ceiling Fans	18	19,603	$ 2.454	28%
Cool Roofs	107	19,710	$ 16.810	28%

Measures	MW Savings	Cum. MW Savings	Levelized Capacity Cost $/kW	Cum. Percent Savings
Dbl Pane Wndw, Low-E	1,295	1,295	$ 17	8%
Duct Insulation	37	1,332	$ 83	8%
Water Heater Blanket	12	1,344	$ 87	9%
Thermal Expansion Valve	162	1,506	$ 97	10%
Prog.Thermostat	47	1,553	$ 149	10%
Pipe Wrap	2	1,555	$ 164	10%
HE Pool Pump and Motor	205	1,760	$ 165	11%
Basic HVAC Testing/Repair	223	1,983	$ 189	13%
HE Tube Fluorescent	28	2,012	$ 192	13%
Duct Repair	104	2,116	$ 219	13%
HE Clothes Washer	120	2,235	$ 233	14%
Low Flow Showerhead	4	2,240	$ 272	14%
Wall Insulation	51	2,290	$ 308	15%
Faucet Aerators	3	2,293	$ 321	15%
Ceiling Insulation	99	2,392	$ 341	15%
HE Room Air Conditioner	55	2,448	$ 342	16%
CFLs	570	3,018	$ 415	19%
Default Window w/ Snscrn	555	3,572	$ 454	23%
Direct Evaporative Cooler	281	3,854	$ 457	25%
HE Freezer	25	3,878	$ 469	25%
Refrigerator - Early Replace	560	4,438	$ 502	28%
HE Water Heater	9	4,448	$ 594	28%
Attic Venting	68	4,516	$ 768	29%
Central Air Conditioner	571	5,088	$ 897	32%
Whole House Fans	155	5,243	$ 899	33%
HE Refrigerator	140	5,383	$ 926	34%
Energy Star Dishwasher	17	5,400	$ 991	34%
HE Clothes Dryer	25	5,425	$ 1,238	35%
Heat Pump Water Heater	60	5,485	$ 1,496	35%
Infiltration Reduction	10	5,495	$ 1,966	35%
Ceiling Fans	12	5,507	$ 3,649	35%
Solar Water Heat	25	5,532	$ 6,748	35%
Cool Roofs	111	5,643	$ 16,125	36%
Floor Insulation	-	5,643	N/A	36%
Heat Pump Space Heater	-	5,643	N/A	36%

For the second refrigerator measure assessment, we calculated two sets of technical potential estimates: (1) assuming current second-refrigerator energy consumption levels (averaging about 1,070 kWh per year per unit); and (2) assuming all second units were currently at ENERGY STAR consumption levels (averaging about 550 kWh per year per unit). The second assumption is consistent with the supply curve concept, where all other refrigerator energy-efficiency measures are applied prior to the second refrigerator measure.

For evaporative coolers, we also calculated two sets of technical potential estimates: (1) assuming the current levels of air conditioner energy consumption (averaging about 950 kWh per home with an air conditioner); and (2) assuming all other cooling energy-efficiency measures had been implemented first (reducing the average air conditioner use to about 250 kWh per home with an air conditioner).

Figure 6-12 shows the technical potential for the second refrigerator and evaporative cooler measures as compared to the base technical potential developed for all the other measures in our study, assuming current energy consumption levels. Figure 6-13 shows the technical potential for the same measures after accounting for energy savings potential for all other measures in the study (including the ENERGY STAR refrigerator measure).

Figure 6-12
Technical Potential for Second Refrigerator Removal and Evaporative Coolers Assuming Current Energy Consumption Levels

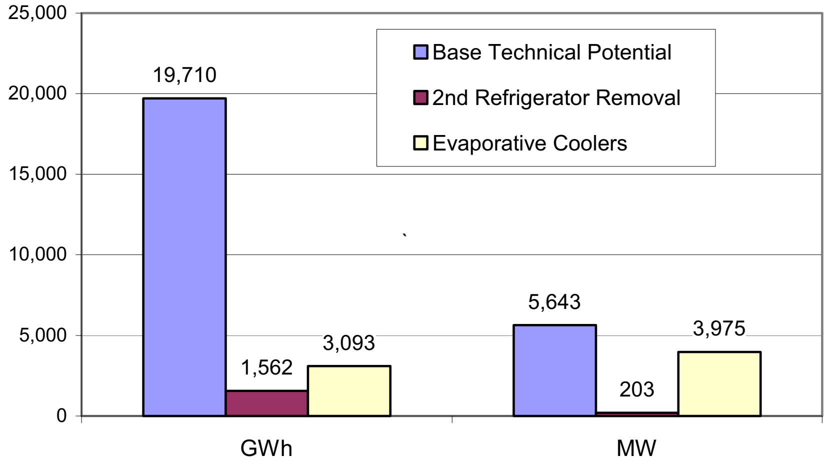
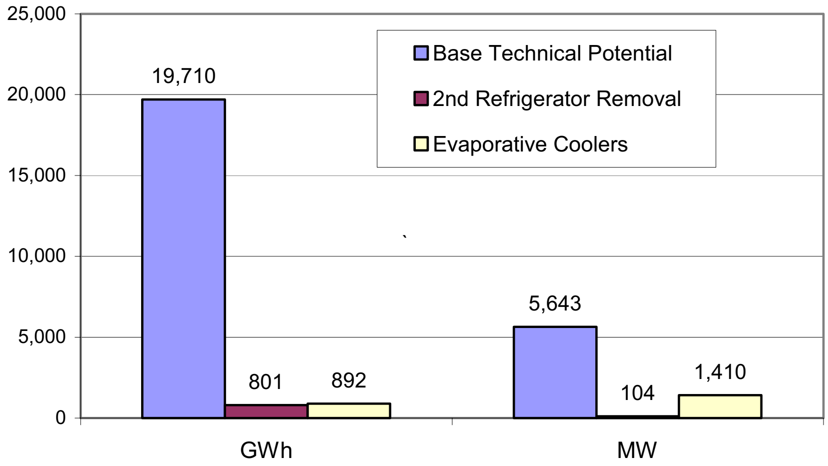


Figure 6-13
Technical Potential for Second Refrigerator Removal and Evaporative Coolers After Accounting for All Other Energy Efficiency Measures



When evaluated using current energy consumption levels, technical energy savings potential for the second refrigerator and evaporative cooler measures is equal to about 24 percent of base technical potential, and technical peak demand potential for these measures is equal to about 74 percent of base technical potential. However, this additional technical potential cannot be added to base potential because there is overlap between these measures and other space cooling and refrigerator measures. After accounting for overlap by first taking into consideration potential savings from other measures, incremental technical potential for second refrigerator removal and evaporative coolers decreases substantially, to 9 percent of base technical energy savings potential and 27 percent of base technical demand savings potential. Potential for evaporative coolers savings declines the most when overlap is taken into account, because there are many more alternative space-cooling measures that could be used to reduce cooling loads.

6.3 ELECTRIC ECONOMIC POTENTIAL UNDER LOW AND HIGH ENERGY COSTS

In this subsection, we present estimates of economic potential under both the Low and High economic scenarios defined in Section 5. Note that technical potential is not presented for the Low and High energy cost scenarios because only the economic potential depends on assumptions associated with avoided costs. Technical potential is estimated, as described in Section 4, independent of measure economics. Thus, this subsection focuses on presenting differences in economic potential among the three scenarios.

The overall economic potential for each energy cost scenario is shown in Figures 6-14 and 6-15 on an absolute and a percent of total sector load basis, respectively. Economic potential is fairly sensitive to the decrease in avoided costs in the Low energy costs scenario, dropping by 37 percent to approximately 9,500 GWh energy savings potential and dropping 28 percent to about 2,600 peak demand savings potential as compared to the Base scenario. Economic potential under the High energy costs scenario is similar to that of the Base scenario, with an increase of 8 percent for energy savings and 3 percent for peak demand savings. The spread of economic potential under uncertain avoided costs is quite large, ranging from roughly 9,500 GWh to 15,200 GWh, which represents a range from 13 to 22 percent of base consumption. The difference in demand potential under the full range of avoided costs is 1,100 MW, representing a range from 16 to 23 percent of base consumption.

Figure 6-14
Residential Electric Economic Potential By Energy Cost Scenario

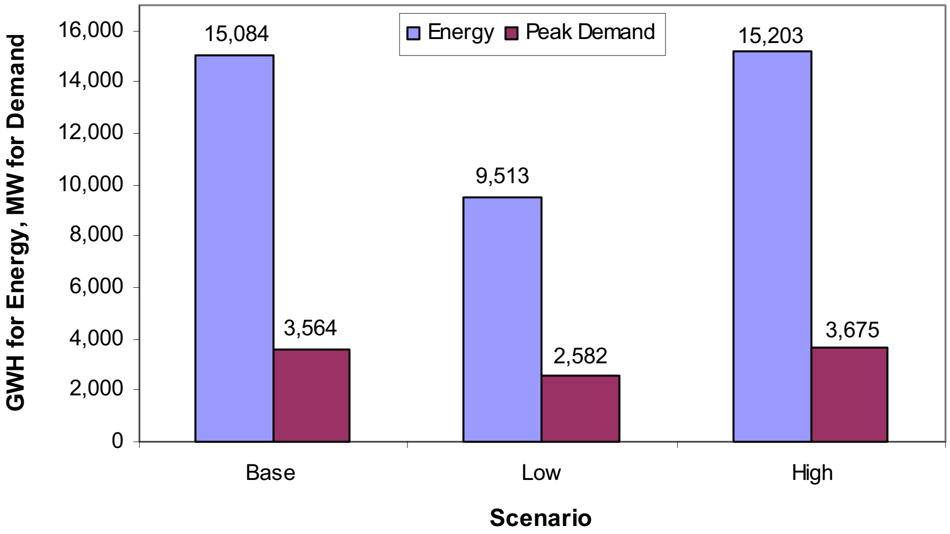
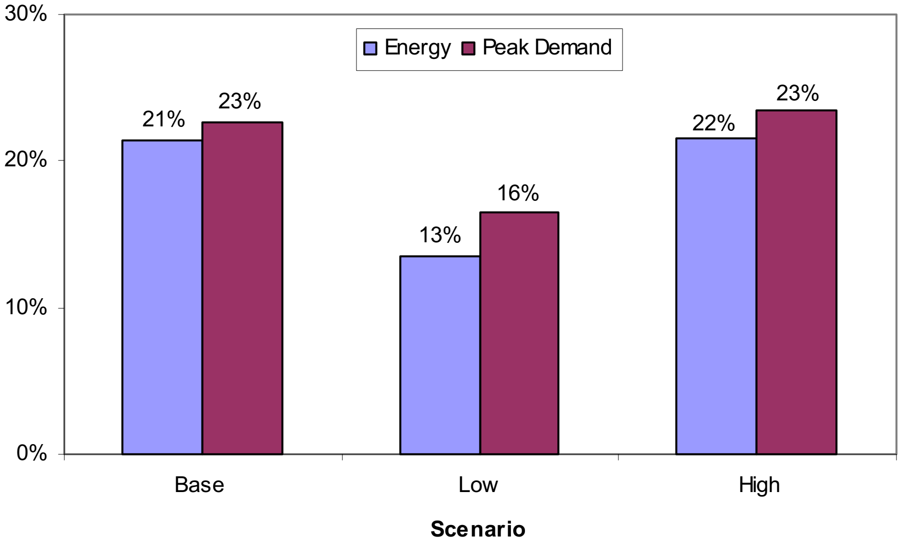
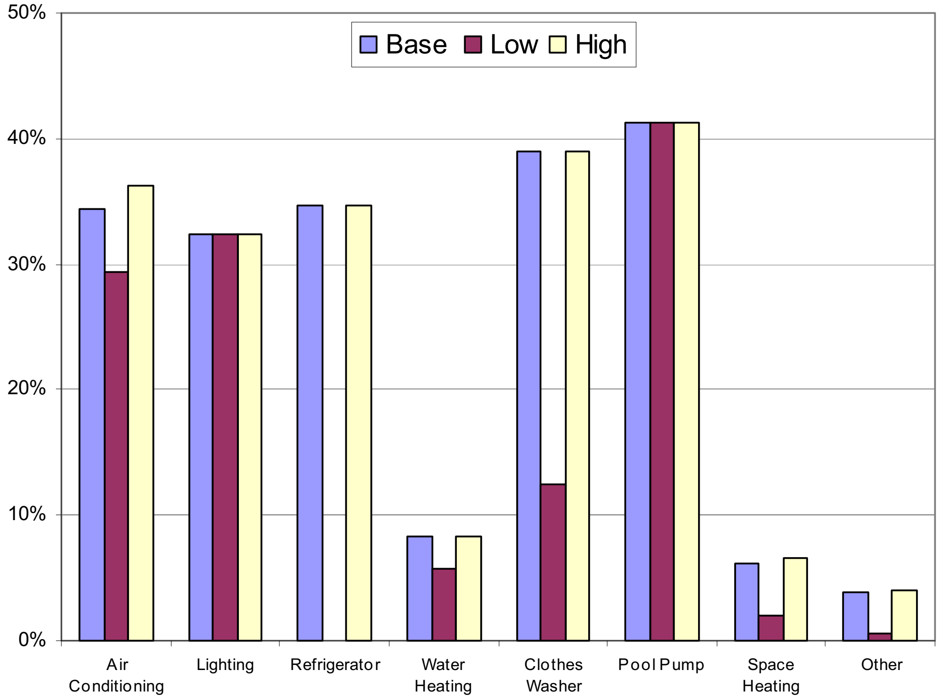


Figure 6-15
Electric Economic Potential as Percent of Base Consumption and Peak Demand
By Energy Cost Scenario



Results by end use are compared in Figure 6-16. In most cases the potential by end use in the Base and High scenarios are virtually identical. The potential for pool pumps and lighting are equal, regardless of cost scenario, while economic savings potential for refrigerators drops out completely in the Low cost scenario.

Figure 6-16
Electric Economic Potential as Percent of Base End-Use Consumption by Energy Cost Scenario



7

NATURAL GAS TECHNICAL AND ECONOMIC POTENTIAL RESULTS

This section provides our estimates of natural gas technical and economic energy-efficiency potential for the existing construction portion of the residential sector of the major investor-owned utility (IOU) service territories. We find that there are untapped natural gas savings potentials still available. Technical energy savings potential is estimated to be 2,148 millions of therms (Mth), and economic potential is estimated to be 370 Mth (about 7 percent of expected residential gas consumption).

7.1 INTRODUCTION

A total of 25 residential natural gas measures were included in these analyses. The complete set of measures considered was pre-screened to only include those measures that are presently commercially available. Thus, few emerging technologies were included in the analysis. The measure analysis was segmented into three residential building types (single family, multi-family, and mobile homes) for each of the three major natural gas IOU service territories. For weather-sensitive measures, we further segmented by 2 building vintages (pre-1998 and pos-1979) and the 14 California Energy Commission (CEC) forecasting climate zones covering the major gas IOUs. As a result, our analyses were conducted for 885 measure-market segment applications.

The technical and economic potential results are presented in aggregate for each utility, by end-use and measure and in the form of natural gas supply curves. We provide estimates of savings in both absolute and percentage terms, and we express percent savings in two ways: 1) percent of total residential gas consumption; and 2) percent of energy addressed.[1] We base our analysis on the CEC's end-use forecast data for the year 2000.[2] Total base energy is the CEC's estimate of the amount of natural gas consumed for all end uses and building types in the residential sector for the IOUs in 2000.

For natural gas consumption, the total base gas use estimated for 2000 in the major IOUs is roughly 5,000 Mth. Energy-efficiency measures are analyzed for the most important gas-consuming end uses: space heating, water heating, clothes drying, clothes washing, and dishwashing (with the latter two end uses actually affecting energy used to heat water). As shown in Figure 2-21, these end uses account for about 85 percent of total residential natural gas consumption, or about 4,290 Mth. We refer to the energy-efficiency estimates based on the major end uses as the base natural gas use *addressed*. We have not included measures for gas

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[1] Energy addressed only includes consumption for the selected end uses in which energy-efficiency measures were developed for this study.

[2] California Energy Demand, 2000 – 2010, CEC, P200-00-02, June. The CEC provided data on square footage, end-use saturation, and end-use intensity to support this study.

miscellaneous, spa/pool heating, and cooking end uses. These end uses comprise only 15 percent of residential natural gas use.

7.2 NATURAL GAS TECHNICAL AND ECONOMIC POTENTIAL UNDER BASE ENERGY COSTS

This section presents technical and economic potential estimates under the base energy costs described in Section 5. Economic potential under the alternative Low and High energy costs is presented in Section 7.3.

7.2.1 Aggregate Gas Technical and Economic Savings Potential by Utility

In Figure 7-1 we present our estimates of total technical and economic potential for natural gas. In Figure 7-2, we show technical and economic potential by utility. Overall, technical energy savings potential is estimated to be 2,148 Mth, about 43 percent of total residential natural gas usage (i.e., 2,148 Mth Savings ÷ 5,032 Mth of base consumption) and 50 percent of the base energy addressed (i.e., 2,148 ÷ 4,288). Economic potential is estimated to be 370 Mth, about 7 percent total base usage and 8.5 percent of the base energy addressed. Southern California Gas (SCG) is estimated to have the largest share of technical and economic energy savings potential at about 49 percent of the total, followed by Pacific Gas & Electric (PG&E) at 43 percent and San Diego Gas & Electric (SDG&E), with a much smaller service area, at eight percent.

Figure 7-1
Estimated Gas Technical and Economic Potential
(Residential Sector Existing Construction, PG&E/SCG/SDG&E)

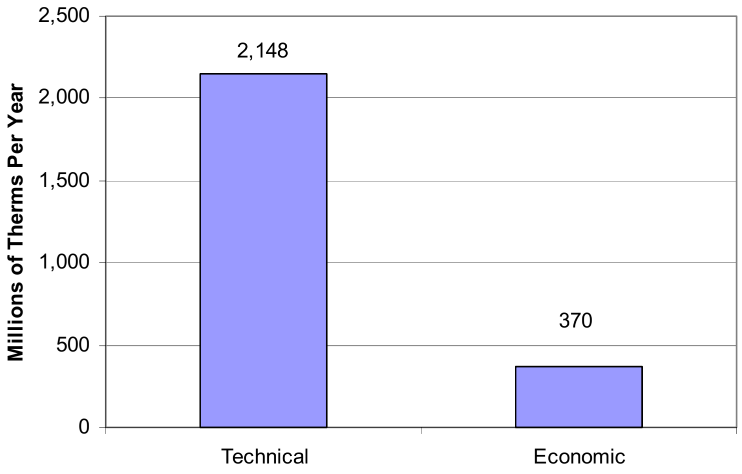
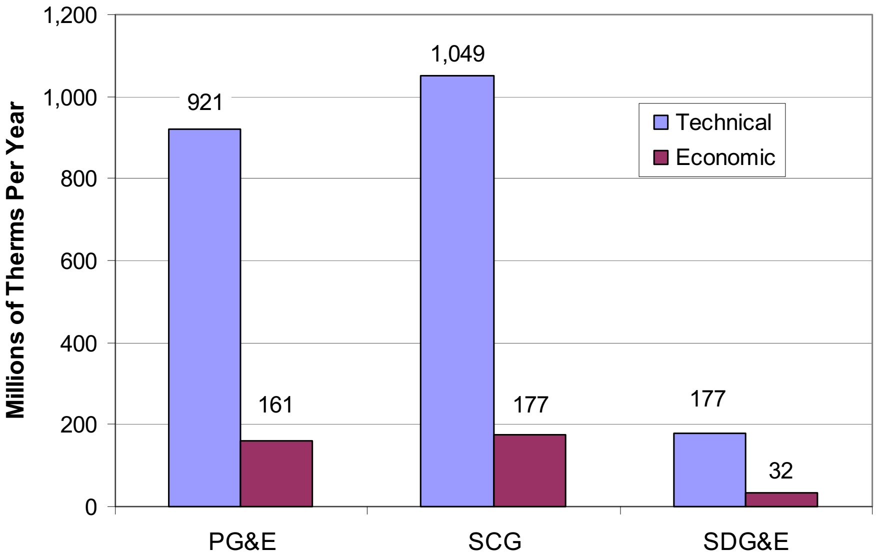


Figure 7-2
Residential Gas Energy Savings Potential by Utility



7.2.2 Gas Technical and Economic Savings Potential by End Use and Measure

Estimates of natural gas savings potential are provided by end use in Figures 7-3 and 7-4. The first of the figures provides savings in absolute terms; the second, in terms of the percentage of base end-use energy consumption. Water heating represents the largest end-use savings potential in absolute terms. Space heating potential represents a significant portion of the total gas savings potential. Economic savings potential values are summarized by end use and utility in Table 7-2.

Figure 7-3
Residential Gas Energy Savings Potential by End Use

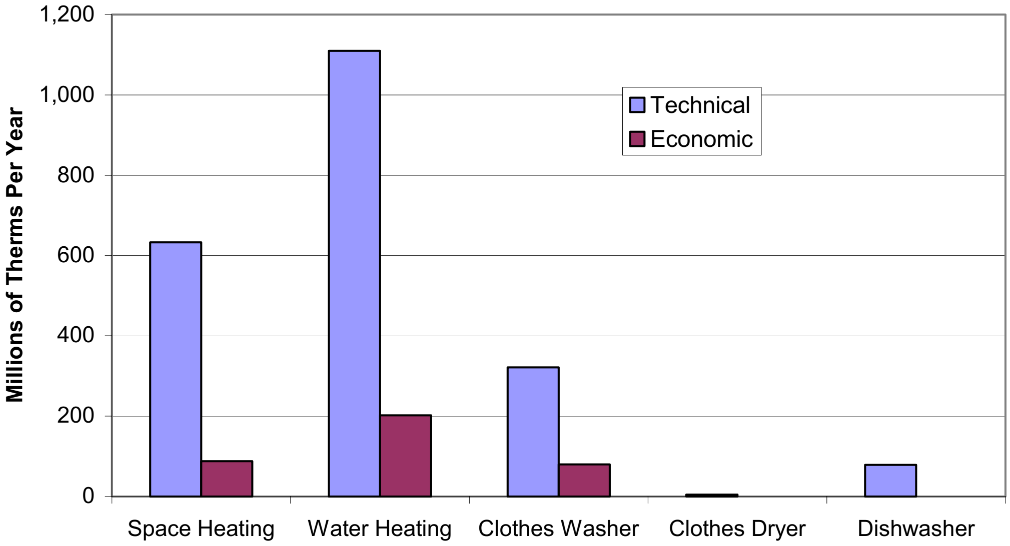


Figure 7-4
Residential Gas Energy Savings Potential as Percent of Base End-Use Consumption

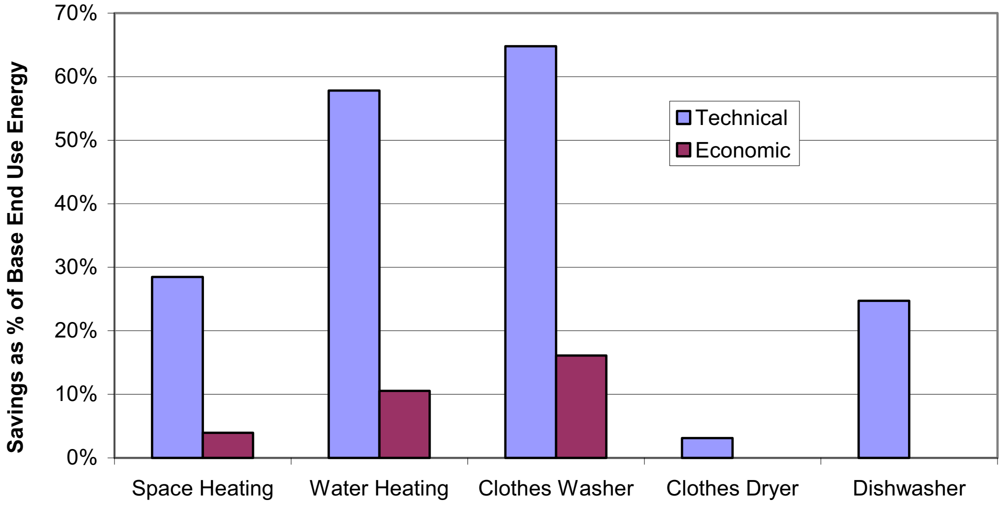


Table 7-1
Residential Gas Economic Savings Potential by End Use and Utility (in Mth)

End Use	**PG&E**	**SCG**	**SDG&E**
Clothes Washer	32	39	9
Space Heating	49	35	4
Water Heating	81	103	19
Total Economic Potential	**161**	**177**	**32**
Total Gas Use	2,173	2,503	356

In Figure 7-5, we present estimates of technical potential by measure. In terms of natural gas savings, solar water heating holds the position as the measure with the largest potential at 39 percent of total technical potential. Horizontal access clothes washers, at 15 percent of the total, condensing furnaces, at 9 percent of the total, and wall insulation in older homes, at 7 percent of the total, are the next largest measures in terms of technical potential. The remaining measures together represent 30 percent of the total technical potential.

Table 7-2 provides a summary of issues and observations associated with these results.

Figure 7-5
Residential Gas Energy Savings Potential by Measure

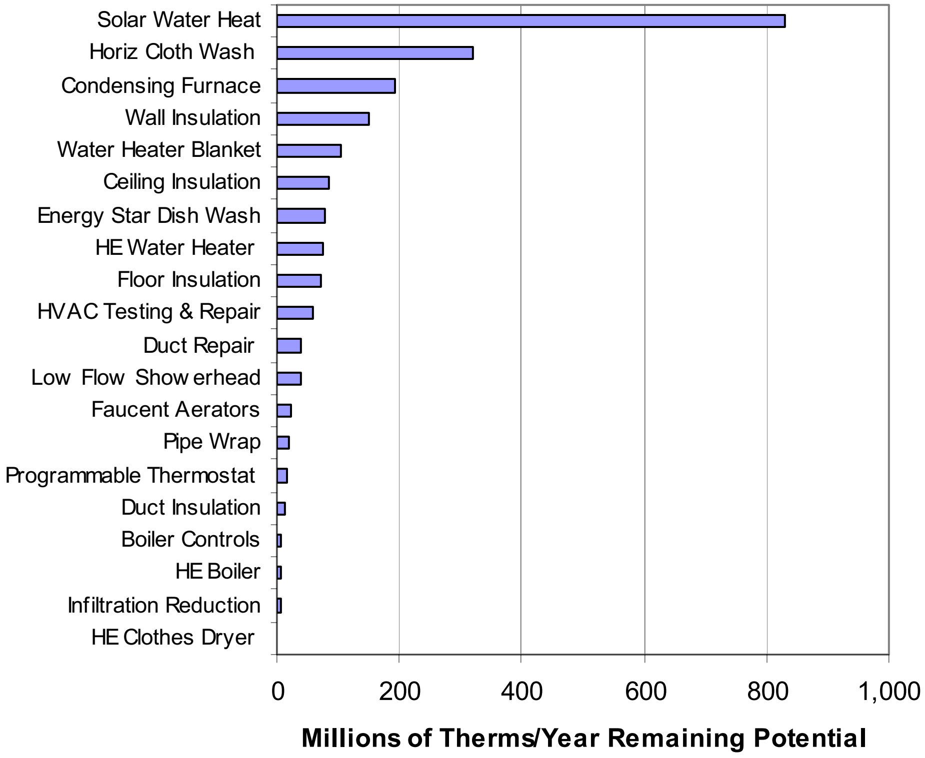


Table 7-2
Considerations for Interpreting Results for Residential Gas Potential

End Use	Key Considerations
Space Heating	1) ***Insulation***. The cost-effective insulation measures were the addition of ceiling insulation in un-insulated homes and the addition of duct insulation to un-insulated ducts. These measures apply only to about 25 percent of the homes built before the advent of Title 24 building standards (pre-1979 homes) and have insufficient levels of insulation. 2) ***Condensing Furnaces***. These higher efficiency, higher cost furnaces were not found to be cost-effective when assessed using consumption data that are aggregated to the CEC climate zone level. However, furnaces may be economically applicable in more extreme microclimates, especially when installed in older, less-efficient homes. As these condensing furnaces become more well known, we may see their incremental costs to go down, making them more cost effective.

End Use	Key Considerations
Water Heating	1) ***Base Water Heater***. For this study, a water heater with an energy factor (EF) of 0.60 was used as the base technology, despite the fact that minimum efficiency standards allow units with an EF of 0.54. In many cases, costs of 0.60 EF water heaters are similar to costs of 0.54 EF water heaters, and the majority of units currently being installed have 0.60+ EFs (RER 2000b, RLW 2000). 2) ***Feasibility and Cost of Key Measures***. Key measures that apply to the water heating end use include water-heater blankets, pipe wrap, low-flow showerheads, and faucet aerators. These measures were modeled as low-cost, do-it-yourself measures and were found to be very cost effective. However, relatively low current penetration rates for these measures [for example, only 24 percent of all water heaters have blankets (RLW 2000)] may provide an indication that there are substantial customer-side costs that are not adequately reflected in our cost-effectiveness analyses, or that some of these measures have pretty much saturated the feasible market. Lack of data on the current saturation of low-flow water devices limits the accuracy of our estimates of savings associated with these measures.
Clothes Washing	1) ***High-Efficiency Clothes Washers***. Horizontal-axis clothes washers were determined to be cost effective only in multifamily setting where a single washer serves multiple dwelling units [an estimate of 10 units per clothes washer was used for this study, based on recent survey data (ADM 2000)]. Our cost-effectiveness analysis only looks at natural gas savings due to reduced hot water usage and does not factor in cost effects of water and detergent savings, nor the effects of reduced clothes dryer usage resulting from higher spin cycle speeds that leave less moisture in clothes.

7.2.3 Natural Gas Energy-Efficiency Supply Curves

Our residential sector energy-efficiency supply curves are shown in Figure 7-6 for natural gas savings potential. The curves are shown in terms of savings as a percentage of total residential sector natural gas consumption for the three utilities in the scope.

In Table 7-3 we show aggregated energy supply curve values by measure. These results are aggregated across market segments and utilities. Individual segment results can vary significantly from the aggregated average values shown. Detailed economic results for individual measures by market segment are provided in Appendix G. (Note, the results in this appendix are not additive because savings for one measure may reduce the energy-efficiency potential for other measures in a given end use, and this interaction is not captured in a measure-by-measure analysis).

Figure 7-6
Residential Gas Energy-Efficiency Supply Curve

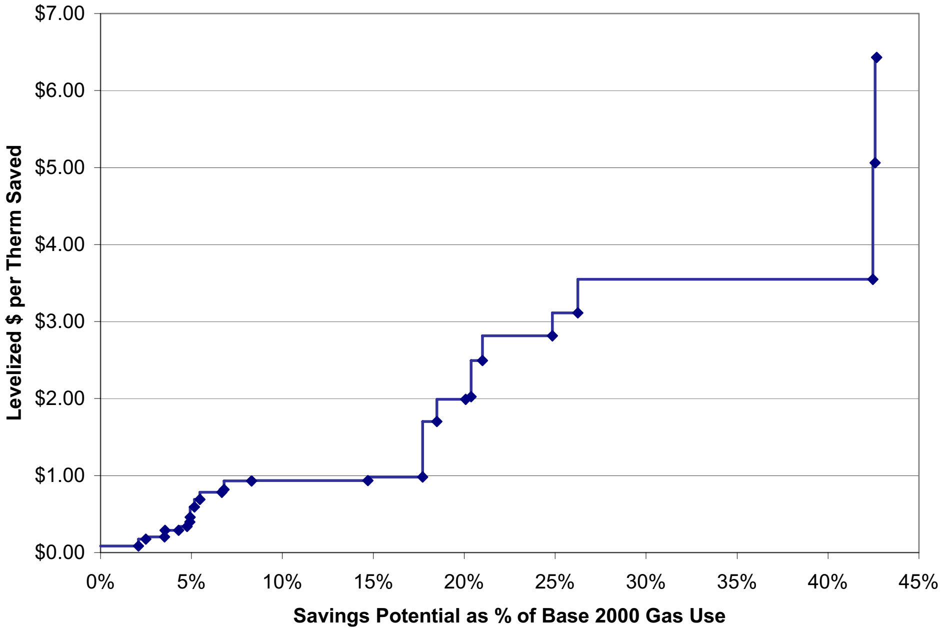


Table 7-3
Aggregated Measure Values for Energy-Efficiency Supply Curves for Residential Gas

Measures	Mth Savings	Cumulative Mth Savings	Levelized Energy Cost $/Therm	Cumulative Percent Savings
Water Heater Blanket	105	105	$0.08	2%
Pipe Wrap	20	125	$0.17	2%
Low-Flow Showerhead	39	164	$0.29	3%
Faucet Aerators	24	188	$0.34	4%
Boiler Controls	8	196	$0.40	4%
Duct Insulation	12	208	$0.59	4%
Programmable Thermostat	15	223	$0.69	4%
HVAC Testing And Repair	60	284	$0.78	6%
HE Boiler	6	290	$0.82	6%
HE Water Heater	76	366	$0.93	7%
Horiz Access Clothes Washer	322	688	$0.93	14%
Wall Insulation	152	839	$0.98	17%
Ceiling Insulation	84	923	$1.07	18%
Duct Repair	40	963	$1.70	19%
ENERGY STAR Dishwasher	79	1,042	$1.99	21%
Condensing Furnace	193	1,235	$2.82	25%
Floor Insulation	71	1,306	$3.11	26%
Solar Water Heat	831	2,137	$3.52	42%
Infiltration Reduction	6	2,143	$5.06	43%
HE Clothes Dryer	5	2,148	$6.43	43%

7.3 NATURAL GAS ECONOMIC POTENTIAL UNDER LOW AND HIGH ENERGY COSTS

In this subsection, we present estimates of economic potential under both the Low and High economic scenarios defined in Section 5. Note that technical potential is not presented for the Low and High energy cost scenarios because only economic potential changes in response to the changes in assumptions associated with avoided costs. Technical potential is estimated, as described in Section 4, independent of measure economics. Thus, this subsection focuses on presenting differences in economic potential among the three scenarios.

The overall economic potential for each energy cost scenario is shown in Figures 7-7 and 7-8 on an absolute and a percent of total sector consumption basis, respectively. Economic potential is fairly sensitive to the decrease in avoided costs in the Low energy costs scenario, dropping by about 30 percent for natural gas savings as compared to the Base scenario. Economic potential under the High energy costs scenario is 16 percent above that of the Base scenario. The spread of economic potential under uncertain avoided costs is quite large, ranging from 250 Mth to 443 Mth. Results by end use are compared in Figure 7-9.

Figure 7-7
Residential Gas Economic Potential By Energy Cost Scenario

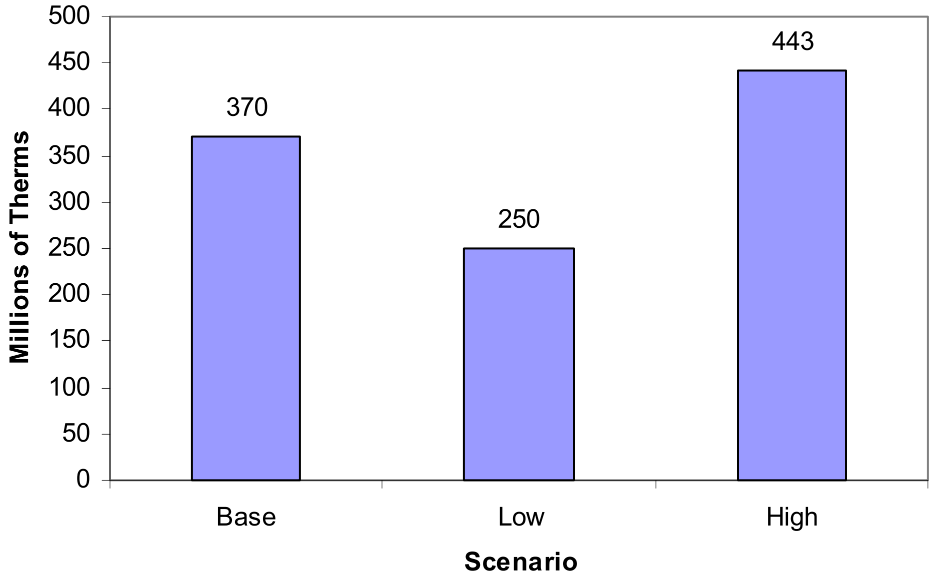


Figure 7-8
Residential Gas Economic Potential as Percent of Base Consumption
By Energy Cost Scenario

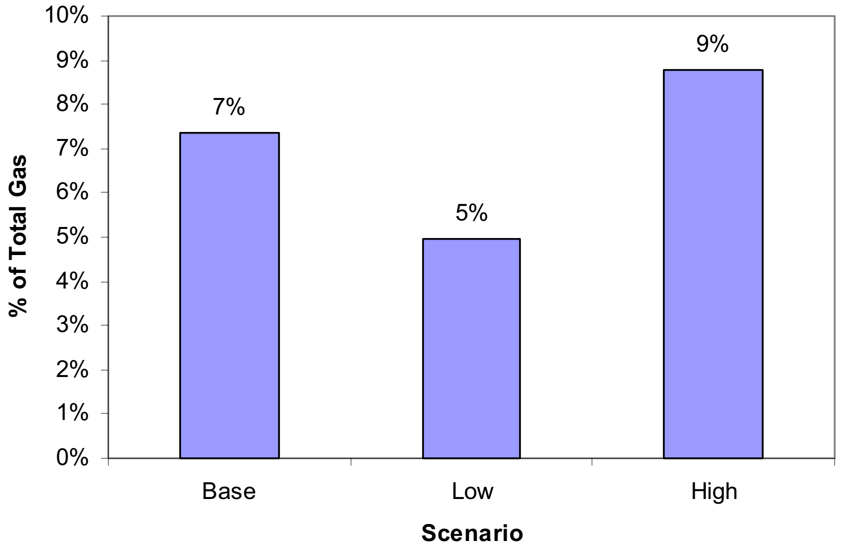
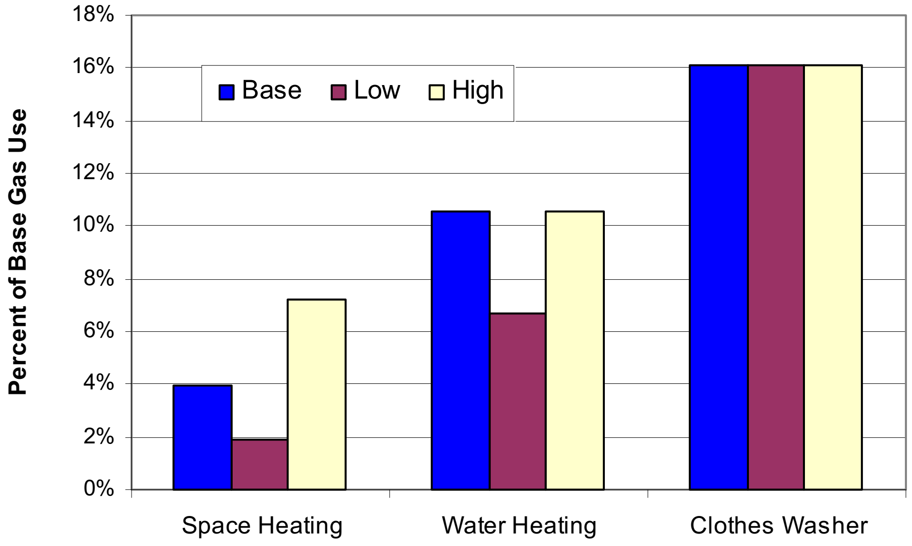


Figure 7-9
Residential Gas Economic Potential as Percent of Base End-Use Consumption
by Energy Cost Scenario



8

RESIDENTIAL ELECTRIC PROGRAM POTENTIAL RESULTS

In this section, we present the results of our achievable program potential estimates for electricity for existing residential households in the major investor-owned utility (IOU) service territories. This section expands on the technical and economic potential results presented in Section 6 to estimate energy-efficiency potential that is realistically achievable in the context of energy-efficiency programs offered by the major electric IOUs. While the results in this section are most relevant to policy makers and planners, these results are also associated with greater uncertainty due to the complexity of the assumptions necessary to estimate program potential.

Program potential is estimated under several scenarios that reflect a range of possible alternative futures. Depending on the electric cost assumptions and program funding levels assumed, our achievable program potential estimates range from net energy savings of 1,300 GWh to 9,800 GWh, and demand savings of 232 MW to 1,800 MW.

8.1 REVIEW OF SCENARIOS UNDER WHICH ACHIEVABLE PROGRAM POTENTIALS ARE ESTIMATED

This subsection summarizes the discussion on development of scenarios presented in Section 5 and the companion report on commercial sector electric-efficiency potential. Readers familiar with this discussion may wish to skip to Section 8.2.

There is some uncertainty associated with virtually all of the inputs to our estimates of energy-efficiency potential. However, the level of uncertainty varies among inputs and not all inputs are equally important to the final results. We determined that the greatest uncertainty in our estimates of economic and program potential is associated with future wholesale and retail electricity prices and future program funding levels. As a result, we limited our scenario analysis for the current study to these two dimensions. Each dimension, energy cost, and funding level is referred to as a scenario element. In Section 5 we described three energy cost elements (Base, Low, and High) and four program funding level elements. These elements are combined into 12 program potential scenarios.

The energy cost scenarios are summarized in Table 8-1 and discussed further in Section 5.

Table 8-1
Summary of Electric Cost Scenario Elements

	Energy Cost Scenario Elements		
Cost Type	**Low**	**Base**	**High**
Avoided Costs	50 percent lower than Base avoided costs.	Avoided-cost averages roughly 3.5 to 19 cents per kWh depending on end use affected.	25 percent higher than Base avoided costs.
Residential Rates	2 cents/kWh less than base.	Start at current levels and then declines by an average of 4 percent per year in real terms over the period 2003 to 2012.	Current actual rates that increase by inflation throughout forecast period.

For each energy cost scenario element, we constructed four different future funding levels. In combination with the energy cost elements, the program funding elements are used to model program potential. Across all energy cost scenarios, the funding level elements are labeled simply Level 1, Level 2, Level 3, and Level 4. Total program funding expenditures increase sequentially from Level 1 to Level 4. Level 1, the lowest expenditure level, generally approximates spending levels in recent years. Level 4, the highest expenditure element, is used to generate our estimates of maximum achievable potential.

As discussed in Section 5, under the Base energy avoided costs, the funding levels are benchmarked to actual funding levels today so that Level 1 represents “Continued Current” levels of funding, Level 2 represents a “50% Increase” above Level 1, Level 3 represents a “100% Increase” over Level 1, and Level 4 represents the “Maximum Achievable” potential, which equates to a 450-percent increase over Level 1 funding. These qualitative funding level scenario labels apply only under the Base energy costs; otherwise (under the Low and High avoided costs) the funding levels are described only with the Level 1 through Level 4 labels. Funding levels are described in detail Section 5 and are summarized with program potential results at the end of this section.

8.2 NATURALLY OCCURRING ELECTRIC SAVINGS RESULTS

Before presenting the net program potential results, we first present our estimates of naturally occurring efficiency savings under our three economic scenario elements. This is because total or gross program potential includes naturally occurring savings. Net program savings exclude naturally occurring savings. It is also useful to examine the estimates of naturally occurring savings under the different economic assumptions because these results are essentially equivalent to bottom-up estimates of the efficiency component of electricity price elasticity.[1]

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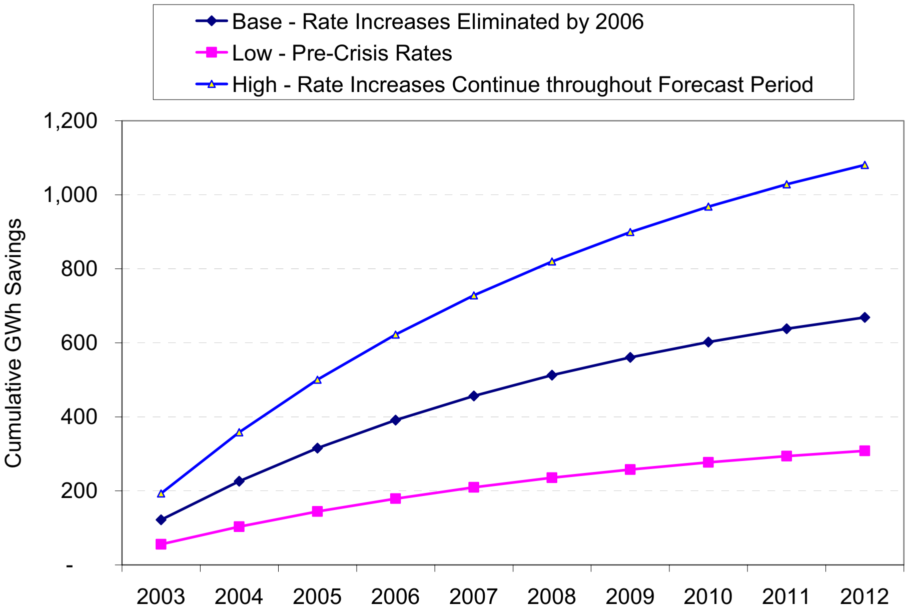
[1] That is, elasticity exclusive of conservation and fuel switching.

Before examining the naturally occurring estimates, readers may want to review the discussion of how customer adoption of efficiency measures is modeled in Section 4. In summary, for the method employed, a customer perspective benefit-cost test is calculated for each measure and market segment. The benefit-cost test uses the forecast of rates for each scenario element over the period 2003 to 2022. The rate forecasts are shown in Section 5 and Appendix B for each scenario. Note that the start year for each analysis is static, i.e., it is always 2003.[2] In addition, by definition the customer adoption behavior is modeled assuming that that the customer bases their decision on the forecasted data as if it were known. For example, in the Base run, the customer "believes" that rates come down steadily over the next 10 years in real dollar terms (the base CEC rate forecast averages a 4 percent per year decrease in real dollars). Under the High scenario, the customer decision is modeled as if the customer "believes" that rates will stay at their current (nominal) levels, increasing by our inflation rate, 3 percent, indefinitely. As noted previously, under the Low energy price forecast, rates are set at 2 cents per kWh below the base throughout the forecast period.

Naturally occurring energy and peak demand savings are shown for the three economic scenario elements in Figures 8-1 and 8-2.

Figure 8-1
Residential Electric Naturally Occurring Efficiency Energy Savings by Economic Scenario



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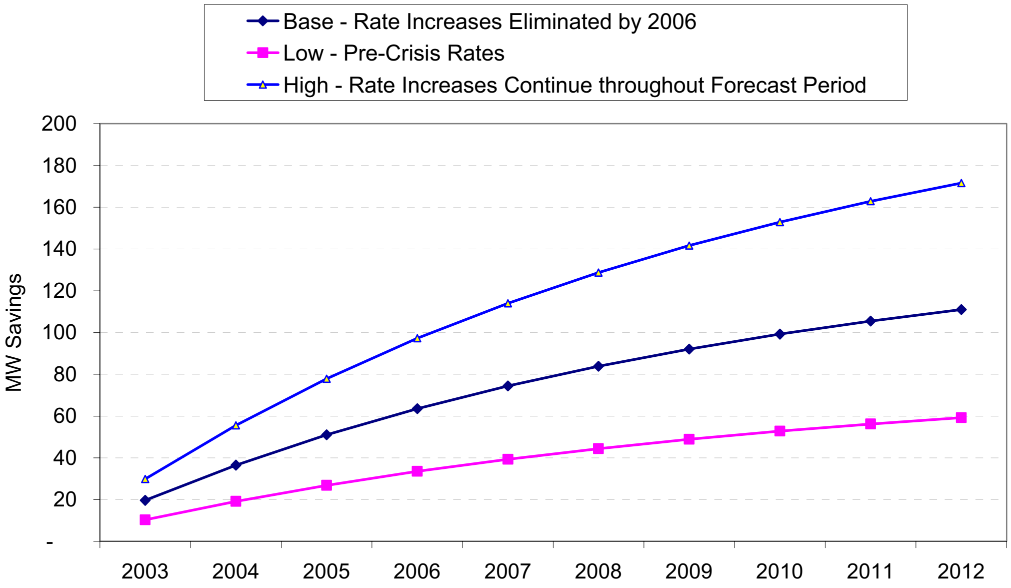
[2] In the modeling process, measures with service lives less than 20 years are assumed to be reinstalled as many times as necessary to equate to a 20-year stream of benefits. Costs of the future-year installations are included in the present value calculations. That is, measure costs and benefits are normalized over a 20-year forecast period.

Figure 8-2
Residential Electric Naturally Occurring Efficiency Peak Demand Savings by Economic Scenario



Annual naturally occurring energy savings under all of the scenarios decrease gradually over the 10-year analysis period. This is principally because, in the absence of further program activity, customer awareness and knowledge of efficiency opportunities is assumed to decline and the existing building stock decays roughly 9 percent. Naturally occurring energy savings under the Base economic cost assumptions start off at roughly 122 GWh per year but average only 67 GWh over the 10-year period (the corresponding peak demand figures are 20 and 11 MW, respectively). In the Low scenario naturally occurring savings are roughly half those in the Base scenario, while the High naturally occurring savings are almost double the Base.

8.3 PROGRAM POTENTIAL RESULTS BY SCENARIO

In this subsection, we present the results from our estimates of residential existing construction program potential under all 12 of the scenarios summarized at the outset of this chapter and defined in Section 5. We forecasted program energy and peak demand savings under each scenario for a 10-year period beginning in 2003. We calibrated our energy-efficiency adoption model, described in Section 4, to actual and planned (2002) program accomplishments. A comparison of our estimated energy savings with actual program savings from 1996 to 2000 is presented at the end of Section 5.

Our estimated energy and peak demand potentials are shown under each energy cost scenario in Figures 8-3 through 8-8. In Table 8-4 (shown at the end of this section), we show the total resource cost (TRC) test results for each scenario, along with total program costs and total impacts in year 10.

8.3.1 Program Potential Under Base Energy Costs

As shown in Figure 8-3 and Table 8-4, under the Base energy costs scenarios, *net* program energy savings potential ranges from about 2,400 GWh under "Continued Current" (Level 1) funding to 9,800 GWh under "Max Achievable" (Level 4) funding. *Net* program peak demand reductions range from approximately 400 MW to 1,800 MW (see Figure 8-4).

"Continued Current" funding under Base energy costs is similar to funding levels in 1996 and 2000, with incentives set at an average of 25 percent of measure costs. Under the "Continued Current" funding with Base energy costs scenario, we estimate that roughly 16 percent of the economic potential of roughly 15,000 GWh (see Section 6) would be captured.

"Max Achievable" funding is 450 percent greater than Level 1 and is an estimate of maximum achievable potential in which incentives eventually cover 100 percent of measure costs and marketing expenditures would make virtually all of the available market aware. Incentive levels are ramped up quickly over time. Under the "Max Achievable" scenario, we estimate that 65 percent of the economic potential could be captured.

Level 2 and Level 3 are scenarios in which expenditures are 50 percent and 100 percent greater than the Level 1 expenditures under the Base energy cost assumptions. Incentives eventually average approximately 40 percent under the "50% Increase" scenario and 55 percent under the "100% Increase" scenario as a percentage of measure costs. Again, incentive levels are ramped up quickly over time.

Figure 8-3
Residential Program Electric Energy Savings Potential by Funding Level
Base Energy Costs (Annual program costs in 2002 real dollars)

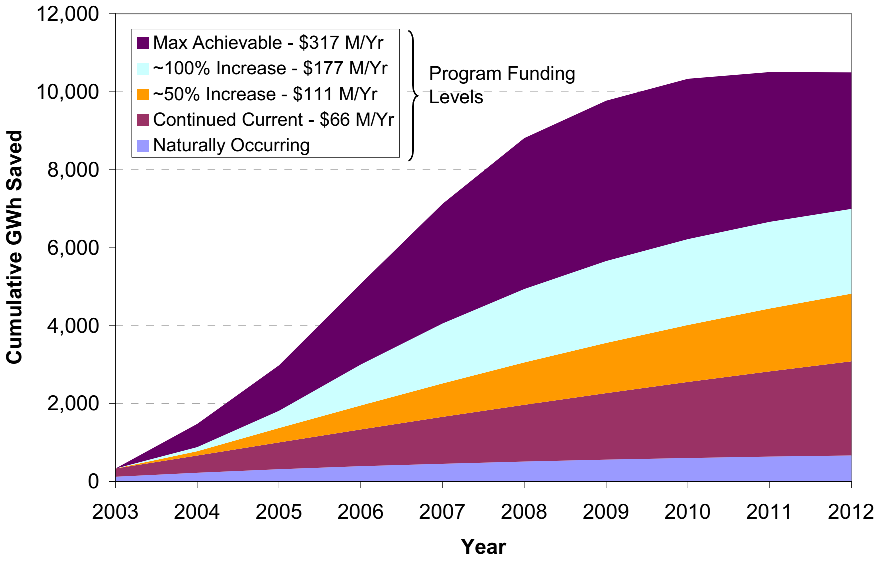
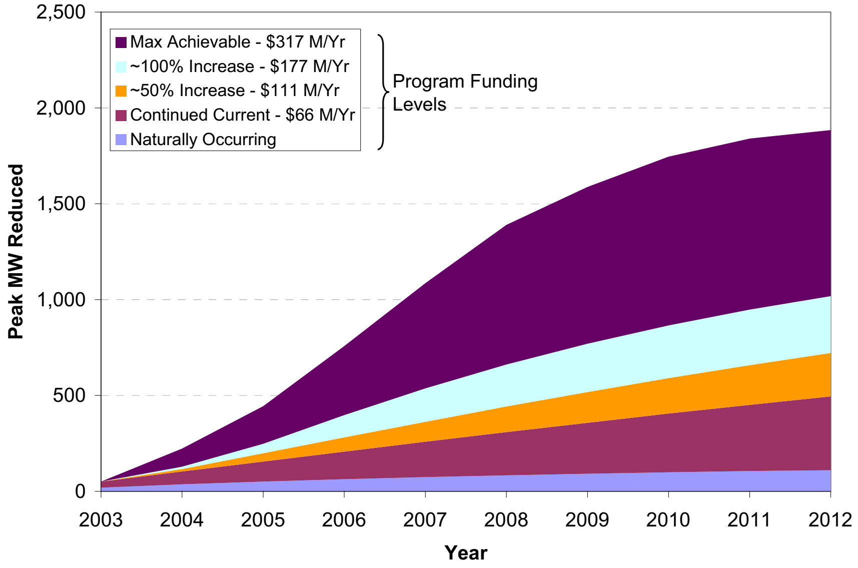


Figure 8-4
Residential Program Peak Demand Reduction Potential by Funding Level
Base Energy Costs (Annual program costs in 2002 real dollars)



8.3.2 *Program Potential by End Use*

Program energy savings potential estimates are summarized by end use in Table 8-2. The largest end use contributors to potential energy savings are lighting and refrigeration. The lighting energy efficiency measures, primarily CFLs, were determined to be more cost-effective that the refrigeration measures. As a result, under most program-funding scenarios, a larger portion of lighting economic potential was estimated to be achievable, relative to the portion of refrigeration economic potential that is achievable.

Table 8-2
Program Electric Energy Savings Potential by End Use (by 2012)

End Use	Total GWh	GWh Potentials						
		Technical	Economic	Max Achievable	~100% Increase Achievable	~50% Increase Achievable	Current Achievable	Naturally Occurring
Air Conditioning	4,728	3,074	1,624	629	262	182	126	42
Clothes Drying	5,476	173	52	12	4	3	2	0.3
Clothes Washing	1,674	654	654	208	170	135	105	23
Dishwashing	2,560	199	133	44	34	26	20	1
Freezer	2,350	181	181	47	5	3	1	0.4
Lighting	19,767	6,847	6,404	4,867	4,431	2,691	1,317	225
Pool Pump	2,535	1,152	1,152	371	220	162	115	16
Refrigeration	12,392	5,391	4,313	3,374	964	736	548	218
Space Heating	2,369	835	251	166	148	131	109	37
Water Heating	2,187	1,203	321	110	88	81	71	106
Other	14,557							
Total	70,595	19,710	15,084	9,826	6,327	4,149	2,413	669

Note: Achievable estimates are net of naturally occurring.

Program peak demand reduction potential estimates are summarized by end use in Table 8-3. The largest end use contributors are air conditioning, refrigeration, and lighting. The relatively large savings potential associated with air conditioning reflects this end use's significant contribution to overall residential peak demand. Lighting contributes a smaller share of peak demand savings potential relative energy savings potential, because only a small fraction of lights are typically on during the peak period (summer weekday afternoons).

Table 8-3
Program Peak Demand Reduction Potential by End Use (by 2012)

End Use	Total MW	MW Potentials Technical	Economic	Max Achievable	~100% Increase Achievable	~50% Increase Achievable	Current Achievable	Naturally Occurring
Air Conditioning	7,382	3,838	2,045	783	312	216	150	46
Clothes Drying	950	25	7	2	1	0.4	0.2	0.04
Clothes Washing	370	120	120	38	31	25	19	4
Dishwashing	268	17	12	4	3	2	2	0.1
Freezer	386	25	25	6	1	0.3	0.2	0.1
Lighting	2,080	598	559	425	387	235	115	20
Pool Pump	543	205	205	66	39	29	20	3
Refrigeration	1,938	700	560	438	125	96	71	28
Water Heating	252	115	31	10	8	8	7	10
Other	1,532							
Total	15,701	5,643	3,564	1,773	907	611	385	111

Note: Achievable estimates are net of naturally occurring.

8.3.3 Program Potential Under High and Low Energy Costs

Estimates of program potential under the Low energy costs scenarios are shown in Figures 8-5 and 8-6. As one would expect, under Low energy costs, net program energy savings potentials are significantly smaller than under Base energy costs, ranging from roughly 1,300 GWh under Level 1 funding to 6,000 GWh under Level 4 funding. The Low scenario potentials decrease relative to the Base potentials as funding levels increase, from 53 percent of the Base potential under Level 1 funding to 61 percent of Base under Level 4. This is because the economic potential and the resulting pool of measures to fund are smaller under the Low scenarios than the Base scenarios (recall from Section 4 that only measures that pass the total resource cost test are included in the program potential analysis). Program peak demand reductions for the Low scenarios range from 200 MW to 1,100 MW.

Estimates of program potential under High energy costs are shown in Figures 8-7 and 8-8. High scenario savings range from roughly 3,400 GWh under Level 1 funding to 9,500 GWh under Level 4 funding. Program peak demand reductions for the High scenarios range from 500 MW to 1,800 MW.

Program energy savings potentials under the High energy cost scenarios are significantly higher than under Base energy costs for funding levels 1 and 2. Net program potentials under the High scenario are 40 percent higher for Level 1 funding than under Base energy costs, but are actually 3 percent lower for Level 4 funding. This is because naturally occurring efficiency savings are higher under the High energy costs scenario than they are under the Base case. The gross savings (i.e., including naturally occurring) are slightly higher under the High case than under the Base energy costs, as can be seen by comparing Figures 8-3 and 8-7 (the cumulative gross savings under the High energy costs are just over 10,600 GWh; while under the Base energy costs cumulative gross savings are just under 10,500 GWh).

Figure 8-5
Residential Electric Program Energy Savings Potential by Funding Level
Low Energy Costs (Annual program costs in 2002 real dollars)

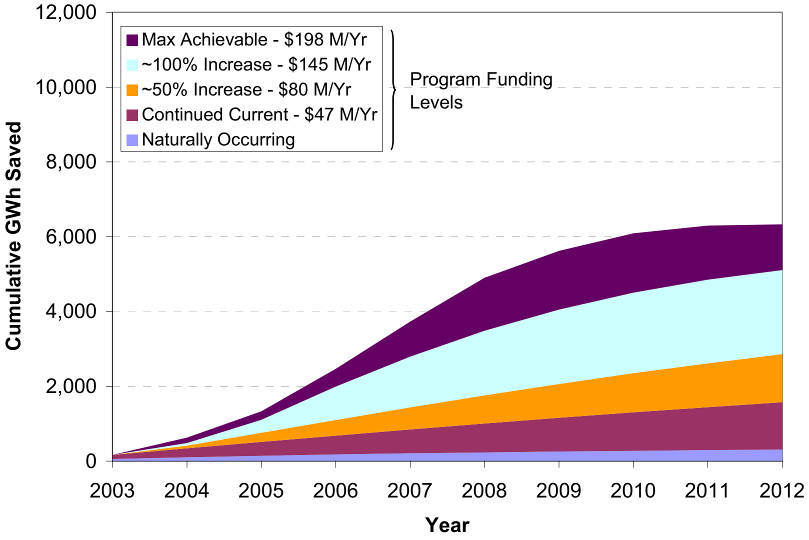


Figure 8-6
Residential Program Peak Demand Reduction Potential by Funding Level Low Energy Costs (Annual program costs in 2002 real dollars)

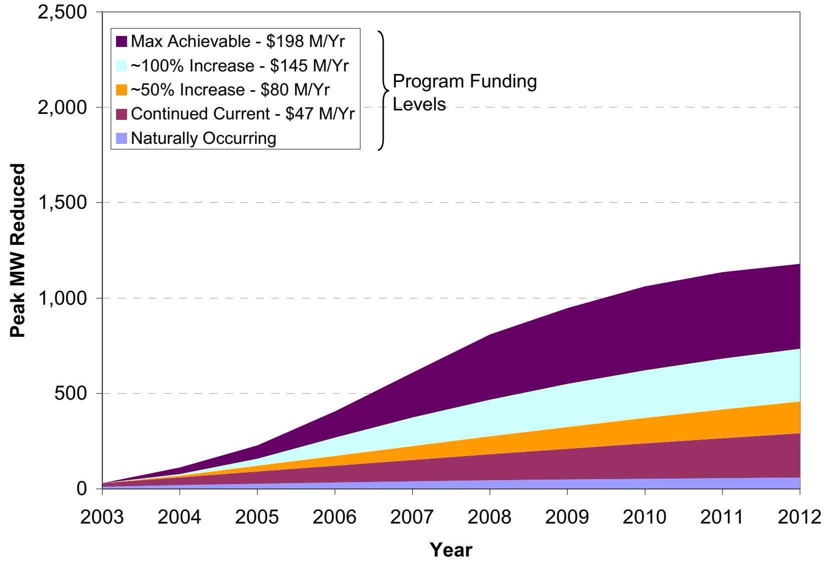


Figure 8-7
Residential Electric Program Energy Savings Potential by Funding Level High Energy Costs (Annual program costs in 2002 real dollars)

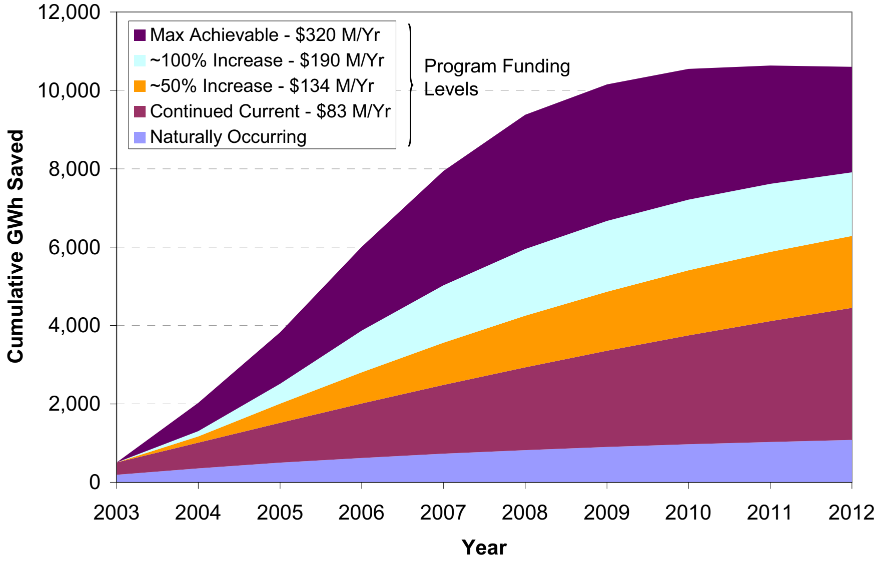
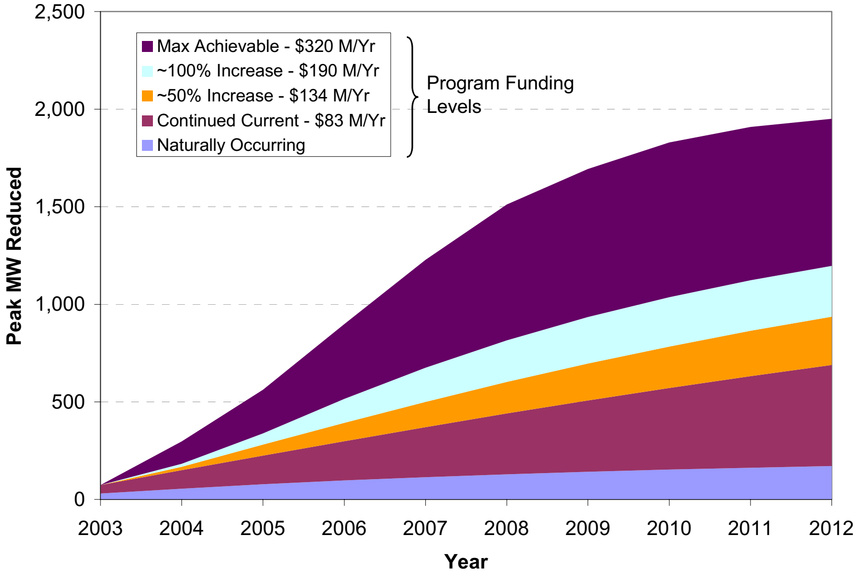


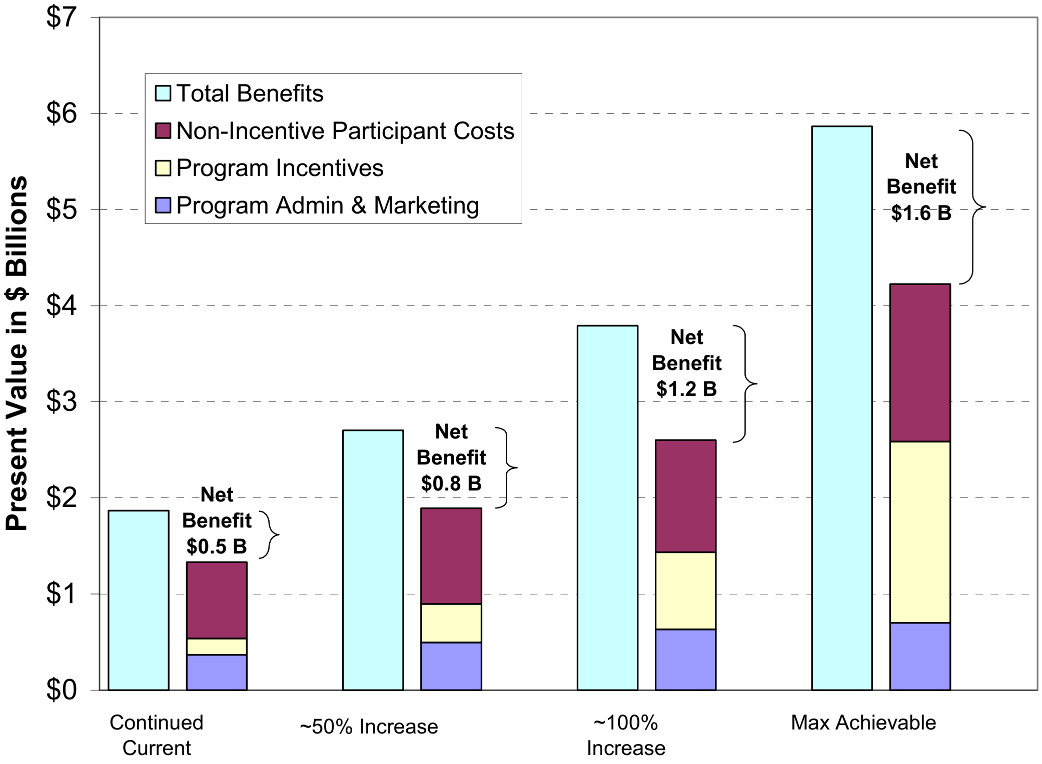
Figure 8-8
Residential Program Peak Demand Reduction Potential by Funding Level
High Energy Costs (Annual program costs in 2002 real dollars)



8.3.4 Cost and Benefit Results

The costs and benefits associated with the residential efficiency funding scenarios under Base energy costs over the 10-year period are shown in Figure 8-9. Total program costs vary from $0.5 billion under the “Continued Current” scenario, to over a $2.5 billion under “Max Achievable.” Total avoided-cost benefits range from $1.9 billion under “Continued Current” to $5.9 billion under “Max Achievable.” Net avoided-cost benefits, which are the difference between total avoided-cost benefits and total resource costs (which include participants’ costs), range from $0.5 billion to $1.6 billion. All of the funding scenarios (under Base energy costs) are cost effective based on the TRC test, which is the principal test used in California to determine program cost effectiveness (see Section 4 for discussion of the TRC test).

Figure 8-9
Costs and Benefits of Residential Electric Efficiency Savings – 2003 to 2012 (under Base Energy Costs Scenario)*



*Value of benefits and costs over life of measures, nominal discount rate = 8 percent, inflation rate = 3 percent.

TRC test and other results are shown in Table 8-4 for all scenario runs. The results shown indicate that all the scenarios are cost effective based on the TRC. TRC values range from a high of 1.8 under High energy costs with Level 3 funding, to a low of 0.9 under the Low energy costs with Level 1 funding. TRC values under the Base energy costs are in the 1.4 to 1.5 range for all funding scenarios. TRC values are much more sensitive to energy cost assumptions than they are to funding levels.

The TRC values remain relatively flat across funding levels due to offsetting factors. First TRC values tend to decrease somewhat as funding levels increase because savings are acquired from measures that are of decreasing cost effectiveness. That is, under the higher funding levels, energy-efficiency opportunities are being purchased from higher and higher on the energy-efficiency supply curve. Countering this trend is the fact that the proportion of net savings increases under the more aggressive scenarios. This is because naturally occurring savings are static across funding levels (since they are by definition unaffected by market interventions) while gross program savings increase substantially; thus the ratio of net-to-gross savings increases across the more aggressive funding levels.

Perhaps somewhat surprisingly to some readers, even the Level 4 maximum achievable funding scenarios, in which marketing costs increase from $21 to $36 million per year and incentives increase from 25 to 100 percent of measure costs ($21 to $231 million per year), are still cost effective under all of the energy cost assumptions. This is partly because incentives are treated as a societal transfer payment in the TRC test and do not affect it directly (see Section 4 for TRC definition). In addition, only those measures that pass the measure-level TRC test are included in the program forecasts.

Table 8-4
Summary of Residential Electric 10-Year Net Program Potential Results*

Scenario		Level 1	Level 2	Level 3	Level 4
Base	Program Costs:	$538 MM	$896 MM	$1,435 MM	$2,588 MM
	Participant Costs:	$794 MM	$997 MM	$1,167 MM	$1,637 MM
	Benefits:	$1,868 MM	$2,704 MM	$3,792 MM	$5,866 MM
	Net GWh Savings:	2,413	4,149	6,327	9,826
	Net MW Savings:	385	611	907	1,773
	Program TRC:	1.40	1.43	1.46	1.39
Low	Program Costs:	$380 MM	$644 MM	$1,166 MM	$1,602 MM
	Participant Costs:	$269 MM	$398 MM	$552 MM	$594 MM
	Benefits:	$579 MM	$942 MM	$1,578 MM	$2,109 MM
	Net GWh Savings:	1,269	2,552	4,800	6,023
	Net MW Savings:	232	399	676	1,120
	Program TRC:	0.89	0.90	0.92	0.96
High	Program Costs:	$681 MM	$1,088 MM	$1,560 MM	$2,641 MM
	Participant Costs:	$1,187 MM	$1,381 MM	$1,483 MM	$1,764 MM
	Benefits:	$3,239 MM	$4,303 MM	$5,330 MM	$7,357 MM
	Net GWh Savings:	3,371	5,205	6,832	9,522
	Net MW Savings:	517	764	1,026	1,779
	Program TRC:	1.73	1.74	1.75	1.67

*All costs, energy and demand savings are cumulative amounts through year 10. Program TRC is for the entire 10-year period. The TRC test is described in Section 4. Present value of benefits and costs over 20-year normalized measure lives for 10 program years (2003-2012), nominal discount rate = 8 percent, inflation rate = 3 percent.

9

RESIDENTIAL GAS PROGRAM POTENTIAL RESULTS

In this section, we present the results of our achievable program potential estimates for natural gas for existing residential households in the major investor-owned utility (IOU) service territories. This section expands on the technical and economic potential results presented in Section 7 to estimate energy-efficiency potential that is realistically achievable in the context of energy-efficiency programs offered by the major IOUs.

The results in this section are most relevant to policy makers and planners as they provide information on the optimal levels of funding and where such funding can garner the most cost-effective residential gas savings. The results, nevertheless, are more uncertain than the technical and economic potentials due to the complexity of the assumptions necessary to estimate achievable program potential.

To deal with the increased uncertainty of modeling inputs, program potential is estimated under several scenarios that reflect a range of possible alternative futures. Depending on the natural gas cost assumptions and program funding levels assumed, our achievable program potential estimates (over the next 10 years) range from net savings of 14 Mth to 275 Mth (or between 0.3 percent and 5.5 percent of expected residential gas demand).

Our definition of and methods of estimating achievable program potential are provided in Section 4 of this report.

9.1 REVIEW OF SCENARIOS UNDER WHICH ACHIEVABLE PROGRAM POTENTIALS ARE ESTIMATED

This subsection summarizes the discussion on development of scenarios presented in Section 5 and reviewed in Section 8.1. Readers familiar with this discussion may wish to skip to Section 9.2.

There is some uncertainty associated with virtually all of the inputs to our estimates of energy-efficiency potential. However, the level of uncertainty varies among inputs and not all inputs are equally important to the final results. We determined that the greatest uncertainty in our estimates of economic and program potential is associated with future wholesale and retail natural gas prices and future program funding levels. As a result, we limited our scenario analysis for the current study to these two dimensions. Each dimension, energy cost and funding level, is referred to as a scenario element. In Section 5 we described three energy cost elements (Base, Low, and High) and four program funding level elements. These elements are combined into 12 program potential scenarios.

The energy cost scenarios are summarized in Table 9-1 and discussed further in Section 5.

Table 9-1
Summary of Natural Gas Cost Scenario Elements

	Natural Gas Cost Scenario Elements		
Cost Type	**Low**	**Base**	**High**
Avoided Costs	50 percent lower than Base avoided costs.	Avoided-cost averages roughly 50 cents per therm.	50 percent higher than Base avoided costs.
Residential Rates	50 percent lower than Base rates.	Average 68 cents per therm over 2003 – 2012 forecast period.	50 percent higher than Base rates.

For each energy cost scenario element, we constructed four different future funding levels. In combination with the energy cost elements, the program funding elements are used to model program potential. Across all energy cost scenarios, the funding level elements are labeled simply Level 1, Level 2, Level 3, and Level 4. Total program funding expenditures increase sequentially from Level 1 to Level 4. Level 1, the lowest expenditure level, generally approximates spending levels in recent years. Level 4, the highest expenditure element, is used to generate our estimates of maximum achievable potential.

As discussed in Section 5, under the Base energy avoided costs, the funding levels are benchmarked to recent actual funding levels so that Level 1 represents “Continued Current” levels of funding, Level 2 represents a “50% Increase” above Level 1, Level 3 represents a “100% Increase” over Level 1, and Level 4 represents the “Maximum Achievable” potential, which equates to a 300-percent increase over Level 1 funding. These qualitative funding level scenario labels apply only under the Base energy costs; otherwise (under the Low and High avoided costs) the funding levels are described only with the Level 1 through Level 4 labels. Funding levels are described in detail Section 5 and are summarized with program potential results at the end of this section.

9.2 NATURALLY OCCURRING NATURAL GAS SAVINGS RESULTS

Before presenting the net program potential results, we first present our estimates of naturally occurring efficiency savings under our three economic scenario elements. This is because total or gross program potential includes naturally occurring savings. Net program savings exclude naturally occurring savings. It is also useful to examine the estimates of naturally occurring savings under the different economic assumptions because these results are essentially equivalent to bottom-up estimates of the efficiency component of residential natural gas price elasticity.[1] Before examining the naturally occurring estimates, readers may want to review the discussion of how customer adoption of efficiency measures is modeled in Section 4 and the discussion in

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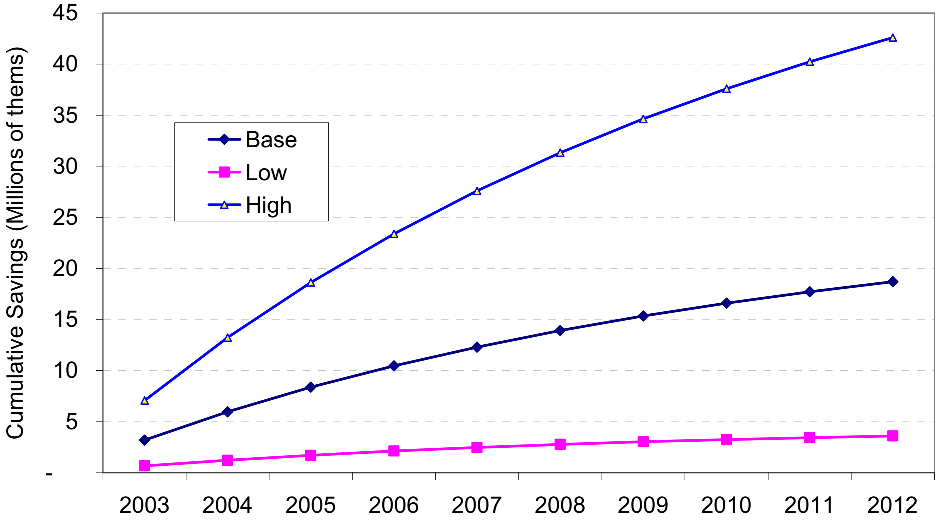
[1] That is, elasticity exclusive of conservation (behavioral changes) and fuel switching.

Section 8.1. Naturally occurring energy savings are shown for the three economic scenario elements in Figure 9-1.

Figure 9-1
Residential Gas Naturally Occurring Efficiency Energy Savings by Economic Scenario



Annual naturally occurring energy savings under all of the scenarios decrease gradually over the 10-year analysis period. This is principally because, in the absence of further program activity, customer awareness and knowledge of efficiency opportunities is assumed to decline and the existing building stock decays roughly 9 percent. Naturally occurring energy savings under the Base economic cost assumptions start off at roughly 3 Mth per year but average 2 Mth over the 10-year period. In the Low scenario naturally occurring savings are roughly 20 percent of those in the Base scenario, while the High naturally occurring savings are over double the Base.

9.3 PROGRAM POTENTIAL RESULTS BY SCENARIO

In this subsection we present the results from our estimates of residential natural gas program potential under all 12 of the scenarios summarized at the outset of this chapter and defined in Section 5. We forecasted program energy savings under each scenario for a 10-year period beginning in 2003. We attempted to calibrate our energy-efficiency adoption model, described in Section 4, to actual and planned (2002) program accomplishments. A comparison of our estimated energy savings with actual program savings from 1996 to 2000 is presented at the end of Section 5.

Our estimated energy potentials are shown under each energy cost scenario in Figures 9-2 through 9-4. In Table 9-3 (shown at the end of this section), we show the total resource cost (TRC) test results for each scenario, along with total program costs and total impacts in year 10.

9.3.1 Program Potential Under Base Energy Costs

As shown in Figure 9-2 and Table 9-3, under the Base energy costs scenarios, net program gas savings potential ranges from 51 Mth under “Continued Current” (Level 1) funding to 238 Mth under “Max Achievable” (Level 4) funding.

“Continued Current” funding under Base energy costs is similar to funding levels in 1995 through 1999, with incentives set at an average of 25 percent of measure costs. Under the “Continued Current” funding with Base energy costs scenario, we estimate that roughly 14 percent of the economic potential of 370 Mth (see Section 7) would be captured. This represents only 1 percent of total residential gas consumption.

“Max Achievable” funding is 300 percent greater than Level 1 and is an estimate of maximum achievable potential in which incentives eventually cover 100 percent of measure costs and marketing expenditures would make virtually all of the available market aware. Incentive levels are ramped up quickly over time. Under the “Max Achievable” scenario, we estimate that 64 percent or 238 Mth of the total economic potential could be captured. This represents about 5.5 percent of total residential gas consumption.

Level 2 and Level 3 are scenarios in which expenditures are targeted to be 50 percent and 100 percent greater than the Level 1 expenditures under the Base energy cost assumptions. Incentives eventually average approximately 40 percent under the “50% Increase” scenario and 55 percent under the “100% Increase” scenario as a percentage of measure costs. Again, incentive levels are ramped up quickly over time. Estimated energy savings under the “50% Increase” and “100% Increase” scenarios are 73 and 109 Mth, or 1.5 percent and 2.2 percent of total residential consumption, respectively.

9.3.2 Program Potential by End Use

Program natural gas savings potential estimates are summarized by end use in Table 9-2. The largest end use contributors to potential energy savings are water heating and space heating, which are, by far, the largest gas end uses. The water heating share of potential declines for lower-funding scenarios because many of the water heating measures (e.g. water heater blankets and low flow showerheads) are associated with higher market barriers which require more program intervention to overcome.

Table 9-2
Program Natural Gas Savings Potential by End Use (by 2012)

End Use	Total Mth	Mth Potentials						
		Technical	Economic	Max Achievable	~100% Increase Achievable	~50% Increase Achievable	Current Achievable	Naturally Occurring
Clothes Drying	147	5						
Clothes Washing	497	322	80	19	11	8	7	3
Dishwashing	320	79						
Space Heating	2,222	633	88	63	42	31	20	9
Water Heating	1,922	1,110	202	156	57	33	24	6
Total	5,108	2,148	370	238	109	73	51	19

Note: Achievable estimates are net of naturally occurring.

9.3.3 Program Potential Under High and Low Energy Costs

Estimates of program potential under the Low energy costs scenarios are shown in Figure 9-3. As one would expect, under Low energy costs, net program energy savings potentials are significantly smaller than under Base energy costs, ranging from roughly 14 Mth (0.3 percent of residential gas use) under Level 1 funding to 157 Mth (3 percent of residential gas use) under Level 4 funding. The Low scenario potentials decrease relative to the Base potentials as funding levels increase, from 27 percent of the Base potential under Level 1 funding to 66 percent of Base under Level 4. This is because the economic potential and the resulting pool of measures to fund are smaller under the Low scenarios than the Base scenarios (recall from Section 4 that only measures that pass the total resource cost test are included in the program potential analysis). Energy savings under Low energy costs for Levels 2 and 3 are 15 Mth (0.3 percent of residential gas use) and 39 Mth (0.8 percent of residential gas use), respectively.

Estimates of program potential under High energy costs are shown in Figure 9-4. High scenario savings range from 86 Mth (1.7 percent of residential gas use) under Level 1 funding to 275 Mth (5.5 percent of residential gas use) under Level 4 funding. Energy savings under High energy costs for Levels 2 and 3 are approximately 83 Mth (1.6 percent) and 153 Mth (3 percent), respectively.

Program energy savings potentials under the High scenarios are significantly higher than under Base energy costs. Net program potentials under the High scenario are 66 percent higher for Level 1 funding than under Base energy costs, and 15 percent higher for Level 4 funding.

Figure 9-2
Residential Natural Gas Program Energy Savings Potential by Funding Level
Base Energy Costs (Annual program costs in 2002 real dollars)

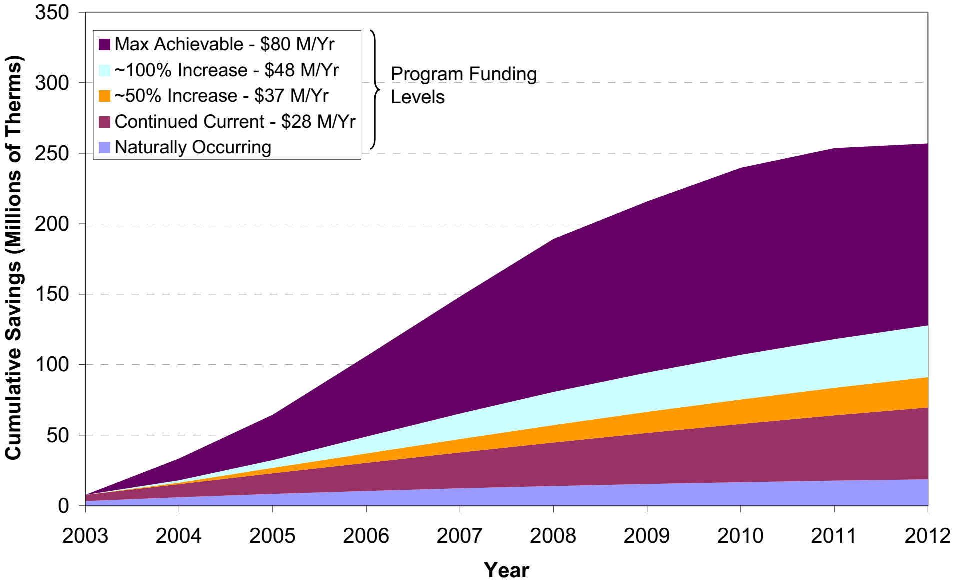


Figure 9-3
Residential Natural Gas Program Energy Savings Potential by Funding Level
Low Energy Costs (Annual program costs in 2002 real dollars)

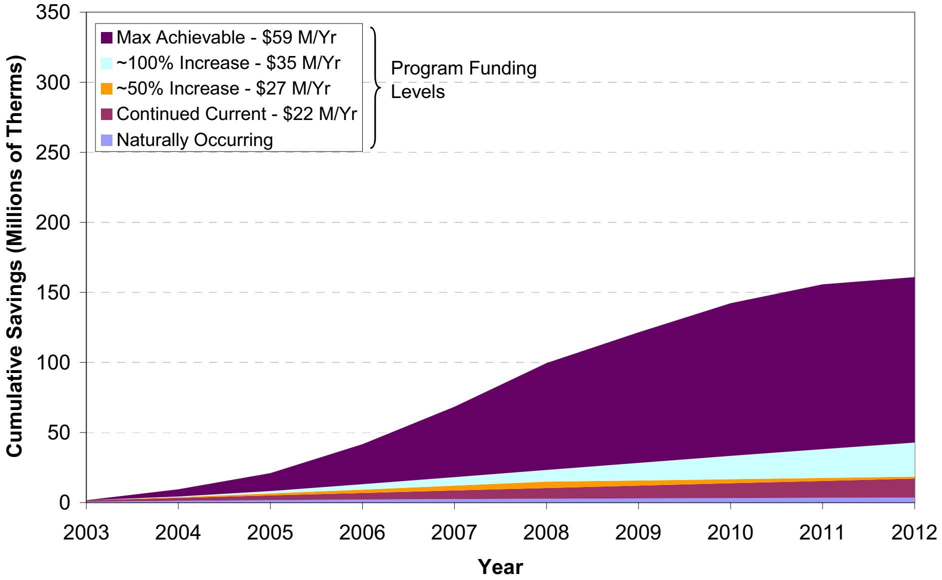
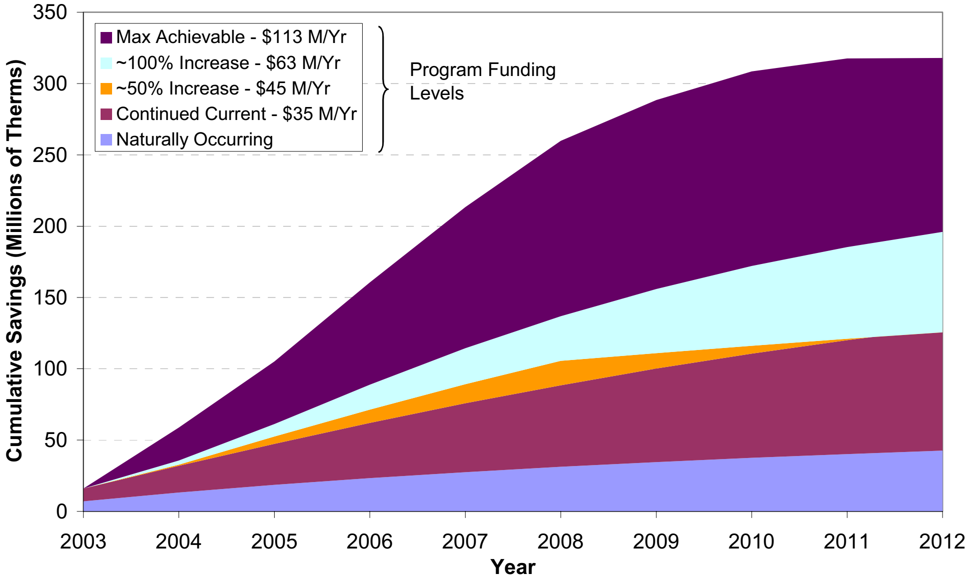


Figure 9-4
Residential Natural Gas Program Energy Savings Potential by Funding Level
High Energy Costs (Annual program costs in 2002 real dollars)

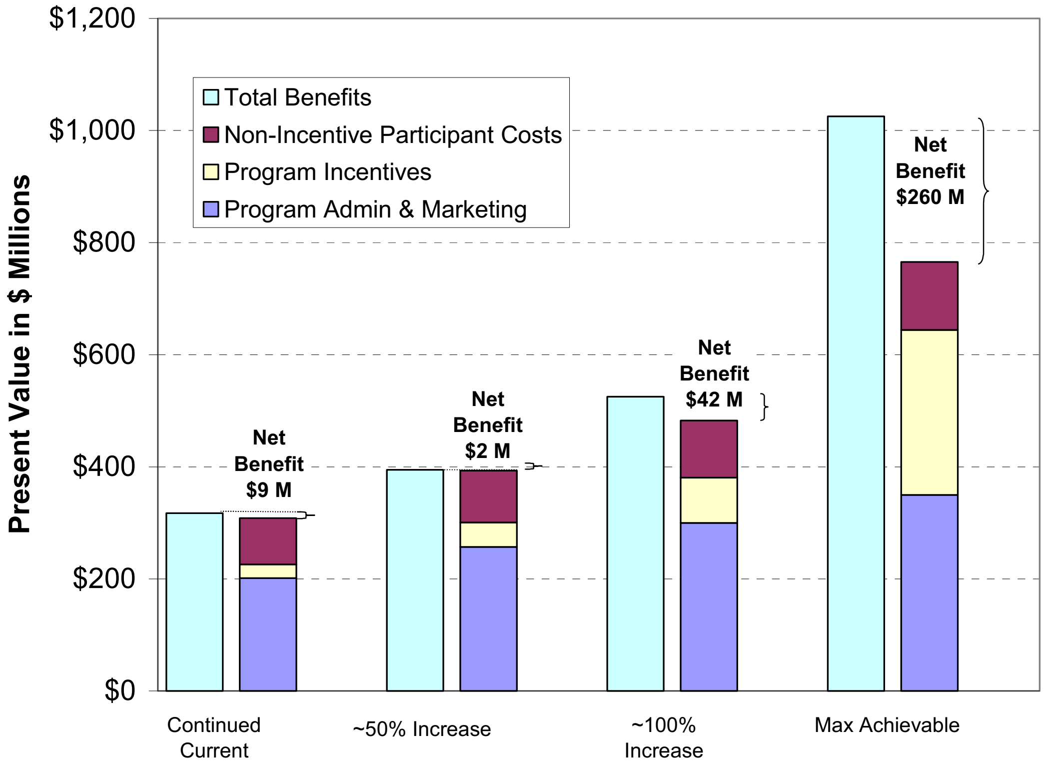


9.3.4 Cost and Benefit Results

The costs and benefits associated with the residential efficiency funding scenarios under Base energy costs over the 10-year period are shown in Figure 9-5. Program costs and avoided costs are very similar for the Base energy cost achievable potential estimates. Net avoided-cost benefits, which are the difference between total avoided-cost benefits and total resource costs (which include participant's costs), range from $2 million under the "~50% Increased Funding" scenario to over a $250 million under "Max Achievable." Net benefits are estimated to decrease from $9 million under the "Business as Usual" scenario to $2 million under the "~50% Increased Funding" scenario due to nonlinearities in the relationship between measure/program costs and measure savings (see Figure 7-6). The fairly large increase in net benefits for the "Max Achievable" scenario result because our penetration analysis shows that fairly high incentives must be paid before energy-efficiency market barriers are overcome, even for cost-effective measures. TRC test and other results are shown in Table 9-3 for all scenario runs.

The results shown indicate that only the High cost scenarios are strongly cost effective based on the TRC. TRC values under Base energy costs are breakeven. Under the Low energy costs scenario, TRC values are well below 1. TRC values range from a high of 1.7 under High energy costs with Level 3 funding, to a low of 0.2 under the Low energy costs with Level 2 funding. TRC values under the Base energy costs hover around 1.0 for Level 1 through Level 3 funding, but rise to 1.3 for Level 4 funding. In contrast to the electric forecasts shown in Section 8, residential natural gas program cost-effectiveness is more sensitive to program funding and energy cost assumptions. However, similar to the electric result, TRC values do not decline with increased funding levels, indicating that increased funding scenarios are estimated to be at least as cost effective as the current funding scenario.

Figure 9-5
Costs and Benefits of Residential Natural Gas Efficiency Savings – 2003 to 2012 (under Base Energy Costs Scenario)*



*Value of benefits and costs over life of measures, nominal discount rate = 8 percent, inflation rate = 3 percent.

Table 9-3
Summary of Residential Natural Gas 10-Year Net Program Potential Results*

Scenario	Result	Level 1	Level 2	Level 3	Level 4
Base	Program Costs:	$226 MM	$301 MM	$381 MM	$644 MM
	Participant Costs:	$82 MM	$92 MM	$102 MM	$122 MM
	Benefits:	$317 MM	$395 MM	$525 MM	$1,025 MM
	Net Therm Savings (in Millions):	51	73	109	238
	Program TRC:	1.03	1.00	1.09	1.34
Low	Program Costs:	$177 MM	$219 MM	$279 MM	$466 MM
	Participant Costs:	$16 MM	$17 MM	$25 MM	$31 MM
	Benefits:	$39 MM	$44 MM	$86 MM	$305 MM
	Net Therm Savings (in Millions):	14	15	39	157
	Program TRC:	0.20	0.19	0.28	0.61
High	Program Costs:	$288 MM	$369 MM	$505 MM	$921 MM
	Participant Costs:	$182 MM	$174 MM	$215 MM	$220 MM
	Benefits:	$870 MM	$892 MM	$1,226 MM	$1,966 MM
	Net Therm Savings (in Millions):	86	83	153	275
	Program TRC:	1.85	1.64	1.71	1.72

*All costs and energy savings are cumulative amounts through year 10. Program TRC values are for the entire 10-year period. The TRC test is described in Section 4. Present value of benefits and costs over 20-year normalized measure lives for 10 program years (2003-2012), nominal discount rate = 8 percent, inflation rate = 3 percent.

10 CONCLUSIONS AND RECOMMENDATIONS

This section presents a brief summary of conclusions, addresses the key issues associated with the results of this study, and provides recommendations for future research.

10.1 SUMMARY OF CONCLUSIONS

Key conclusions from this study are summarized below:

- Over the next 10 years, there is significant remaining achievable and cost-effective potential for electric and natural gas energy-efficiency savings in the residential sector beyond the savings that are likely to occur under continuation of current public goods funding levels.
- Capturing this additional achievable program potential would require an increase in funding levels for energy-efficiency programs.
    - By increasing the amount spent on residential electric programs from $0.5 billion to $1.4 billion over the next 10 years, the state could double program-related benefits, saving an additional $1.9 billion on electricity costs, going from an estimated savings of $1.9 billion under current funding to $3.8 billion.
    - Increasing residential natural gas program spending over the next 10 years from $230 million to $380 million could save an additional $208 million on natural gas costs, going from an estimated savings of $317 million under current funding to $525 million.
- There is considerable uncertainty in two of the principal forecasting inputs necessary for analyzing the cost-effectiveness of energy efficiency: the avoided-cost benefits of efficiency and retail energy rates. Energy-cost scenarios were utilized to address this uncertainty.
- Although there was a significant amount of solid, empirical data upon which to build the analyses conducted for this study, several key data and methodological uncertainties require further work as discussed at the end of this section.

10.2 KEY ISSUES

All of the program-funding scenarios were estimated to be cost effective under the Base energy cost and High energy cost scenarios, but most program funding scenarios were not cost effective under the Low energy cost scenario. As discussed in Sections 8 and 9, all of the program funding scenarios under Base and High energy costs had TRC ratios greater than 1.0, indicating that these scenarios are cost effective. Under Low energy costs, none of the natural gas funding scenarios had TRC ratios greater than 1.0, and only one of the electric funding scenarios had a TRC ratio greater than 1.0. In addition, most of the natural gas funding scenarios under the Base costs had TRC ratios just slightly above 1.0, indicating that these scenarios were only marginally cost effective.

The variation in TRC values across the avoided-cost scenarios was considerably greater than the range of TRC values across funding levels within each avoided-cost scenario. This result was somewhat expected, because incentives are treated as a societal transfer payment in the TRC test and do not directly affect it. In addition, only those measures that passed the measure-level TRC test were included in the program potential estimates.

However, use of a static cost-effectiveness test, like the TRC, does not provide all of the information necessary to determine the optimal level of investment in energy efficiency. While it is useful to know that the majority of the achievable program potential forecasts were cost effective under all of our energy cost scenarios, cost-effectiveness screening does not answer the larger resource-planning question of how much energy efficiency ought to be purchased through the public goods funding process. Although the achievable program potential results are important to consider and understand, it is also important to remember that they are static and deterministic because they are based on static avoided-cost forecasts. The avoided-cost forecasts do not change in response to increasing levels of demand reduction, increases in supply, increases in the percentage of supply from renewable energy, increases in the amount of price-induced conservation behavior, uncertain future events, or to the volatility of underlying fuel prices like natural gas. In short, static avoided costs do not provide adequate information for determining the optimal mix of all possible resources (e.g., energy efficiency, demand response/load management, distributed generation, conventional supply, renewables, etc.). In order to determine the optimal mix of resources, a broader analytical framework is necessary. Developing such a framework was not a part of the current study, though efforts should be undertaken to address this issue in the future.

We believe new analytical methods are needed to improve upon strategic resource planning processes developed during the period of integrated resource planning in the early 1990s. Research is needed that explicitly tackles the question of how investments in demand- and supply-side resources should be optimized in California given the events of the past 2 years. We need an approach that builds on the lessons learned from both the integrated resource planning period of the late 1980s and early 1990s and the market-based experiments of the last 5 years. Such an approach would require supply-side forecasts and integration analyses that incorporate price uncertainty, price volatility, and significant probabilities of future energy “events” such as supply shortages and concomitant price spikes.

Historically, the development of energy-efficiency strategy has been based on integrated resource plans. While this work was admirable, its core elements were based directly on supply planning, planning that was grounded on an investment paradigm that focused on the net present value of revenue and cost streams.[1] By contrast, modern investment theory considers not only the

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[1] For example, in many cases a “least cost” resource plan often resulted in a plan, selected solely on expected costs, that relied on a single type of resource to meet most or all of a utility’s new resource needs.

revenue and cost streams, but also the uncertainty around those streams. This consideration of risk causes modern finance to seek methods of risk mitigation that cause the risk taken to be commensurate with the likely return. The level of cost uncertainty or volatility seen in electricity markets is very high when compared with many other commodity markets.

To help protect ratepayers from future price uncertainty, energy providers and policymakers need to consider risk mitigation alternatives. Energy efficiency and demand response/load management provide clear risk-management opportunities. These considerations should put energy efficiency in the forefront of policy discussions in contrast to other risk-mitigation alternatives requiring market premiums.

Our estimates of savings are reasonable representations of potential over the near- and mid-term (i.e., the next 5 years or so), but should be viewed as conservative for the longer term (i.e., 10 plus years from the present). This is because, as mentioned in Section 1, the scope of this report focused on the retrofit of existing homes. Retrofit opportunities, though important, are more limited in terms of energy-efficiency potential than are major renovations in which entire systems can be completely redesigned to maximize savings. In the medium term, renovations do not account for a large share of the current existing buildings market, but over the long term such renovation opportunities become more important as a share of the existing stock. In addition, our original scope was also limited to commercially available measures; thus, few emerging technologies are included. This is again appropriate for a medium term view of potential, but as one forecasts further into the future, the effect of excluding emerging technologies is to underestimate long-term potential.

There is a moderate amount of uncertainty around our estimates of technical and economic potential for several measures. As outlined in Table 6-2 in Section 6 (for electricity) and in Table 7-2 in Section 7 (for natural gas), key uncertainties include the following:

- **Cooling.** Stricter air conditioning standards, set to take effect in 2006, were not taken into consideration in this study and will lower program potentials in the later years of our forecast horizon. Double-paned windows with low-E coating are included in this study as a cost-effective measure, but some recent evidence indicates that these windows may soon become standard equipment and may not be available for programs.
- **Lighting.** CFLs account for much of the lighting potential. The technical feasibility of installing large numbers of CFLs in traditional fixtures has not been thoroughly tested.
- **Refrigeration.** A large portion of overall program savings potential is tied to the early replacement of working refrigerators. The window of opportunity for these savings is limited, as naturally occurring replacement will rapidly deplete the stock of older, less-efficient units, thus reducing the per-unit savings of future replacements.
- **Water Heating.** Key measures that apply to the water-heating end use include water heater blankets, pipe wrap, low-flow showerheads, and faucet aerators. These

measures were modeled as low-cost, do-it-yourself measures and were found to be very cost effective. However for water heater blankets, the relatively low current saturation of under 30 percent may provide an indication that there installation feasibility limitation or substantial customer-side costs that are not adequately reflected in our cost-effectiveness analyses. Reliable data on current market saturations of low-flow showerheads and faucet aerators are not available, but it is likely that the saturations of these measures are quite high, with the possible exception of the hard-to-reach market segments, due to standards limiting water flow rates in new fixtures.

While solar water heating provides a source of considerable technical energy-efficiency potential, it was not to be cost effective in typical homes, although higher water-using homes may still benefit from this measure.

10.3 RECOMMENDATIONS FOR FURTHER EFFICIENCY POTENTIAL RESEARCH

Further research is needed to improve both the data and methods required for accurate estimation of residential energy-efficiency potential in California. The primary areas of research needed to reduce uncertainty in key inputs to efficiency potential estimates include the following:

- ***Improve estimates of sustained conservation and efficiency resulting from 2001 energy crisis.*** As is well documented, the energy crisis of 2001 spawned a sharp drop in energy consumption and peak demand, much of which is hypothesized to be attributable to conservation behavior, rather than efficient hardware improvements. For example, a recent study by Lawrence Berkeley National Laboratory (Goldman, Eto, Barbose 2002) estimates that about one-quarter of the 8-percent drop in peak demand in California in 2001 (a decrease of about 1,100 MW) is attributable to equipment-based efficiency and on-site generation installations, which will persist for many years. The remainder of the 2001 reduction in peak demand (approximately 3,300 MW) is attributable to behavioral and energy management practice changes where persistence is difficult to predict.

  Because of the lack of adequate information available during the time of our study on the components and durability of energy and peak demand reductions in 2001, our study used 2000 as the base year for estimates of hardware-based electric efficiency. These estimates will need to be adjusted to account for both permanent efficiency improvements in 2001 (and 2002) and any sustained conservation behavior. On-going research is critically needed to better understand, characterize, and forecast the components of savings (that is, at the sector, end-use, and measure level) associated with the 2001 energy crisis and the extent to which they persist.

- ***Improve forecasts and tracking of customer adoption of efficiency measures.*** Forecasting customer adoption of energy-efficient technologies and practices requires a strong empirical foundation. The key need in this area is further collection and development of historic and current measure penetration data to use as the basis for calibrating forecasting models like those used in this study. A concurrent need is for development of a statewide database of measures adopted with public goods funds or other programmatic support. Currently, there is no measure-level database of all statewide program accomplishments available in a single, consistent format. There is also a need to continue tracking of measure adoption outside of programs (naturally occurring penetration). Currently, there is a successful multi-year project to track the market share of energy-efficient products and practices (this work is managed by Southern California Edison on behalf of the CPUC with public goods funds, see RER 2000b, 2001a and 2001b).

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