CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY

Study ID #SW061

FINAL REPORT

VOLUME 1 OF 2

Main Report

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* Revisions: Figure E-5 (page E-7), Figure 7-5 (page 7-7), and text referring to Figure E-5 on page E-6

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EXECUTIVE SUMMARY

California has long been both a national and international leader in developing programs and policies aimed at increasing the efficiency with which both electricity and natural gas are used in the State. Over the past 25 years, efforts from utility energy-efficiency programs and state standards have culminated in savings of approximately 2,000 million therms (Mth) per year, split fairly evenly between programs and standards.

Yet, natural gas energy savings potential remains. This study finds that more than $70 million would be spent on programs to promote natural gas efficiency in California's commercial sector over the next 10 years if current efficiency program activity levels continue—an investment projected to yield roughly $143 million in avoided cost savings. Further, the study shows that increasing program activity aimed at gas usage in the commercial sector would not only reduce consumption, but also net millions of dollars in additional savings. For example, by increasing commercial natural gas efficiency program activity by 250 percent, the state could save a total of $308 million on natural gas costs.

This is the first commercial natural gas energy-efficiency potential study conducted in California since the early-1990s, and the first statewide study. Recently, a number of factors—supply shortages, price volatility, 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 commercial sector energy efficiency as a cost-effective alternative to increased natural gas supply expenditures.

This study assesses natural gas energy-efficiency potential in existing commercial buildings within the service territories of the three major natural gas investor-owned utilities (IOUs) in California: Pacific Gas and Electric Company (PG&E), Southern California Gas Company (SCG), and San Diego Gas and Electric Company (SDG&E). These utilities account for nearly all of the state's 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 and is available for download at www.calmac.org.

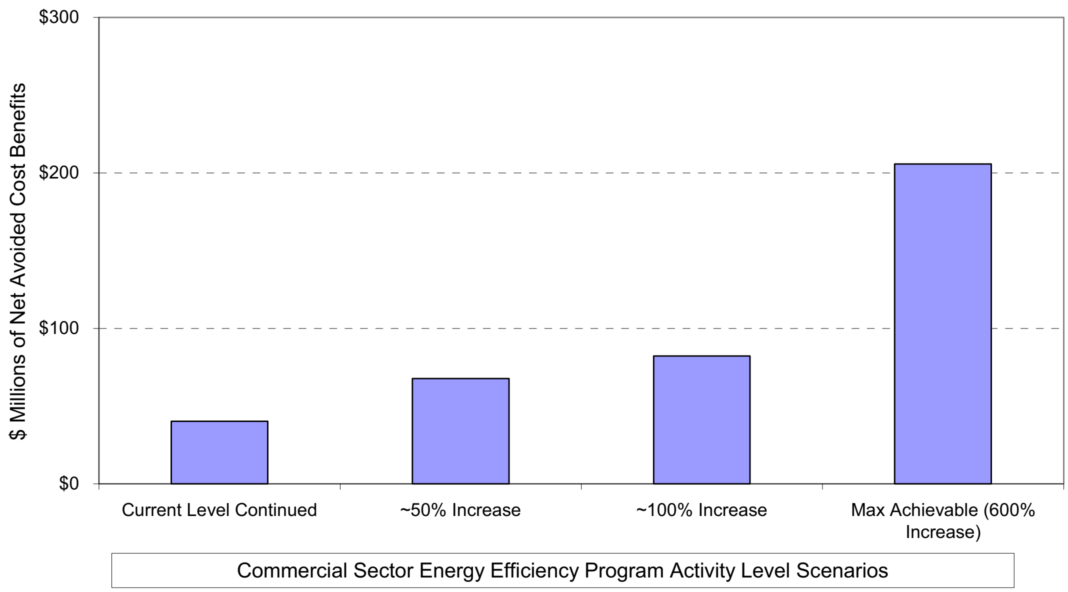
The study is designed to answer a number of research questions important to the planning of future commercial energy-efficiency programs. These include:

- How much near-term commercial sector natural gas 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 gas costs and natural gas rate increases?

Simulating different future program activity levels, the study forecasts program energy savings under three energy cost scenarios (Base, Low, and High). Under the base energy cost forecast, for example, net program natural gas savings potential ranges from roughly 30 Mth under current program activity levels to 75 Mth if current funding is increased by 150 percent. As shown in Figure E-1, net financial savings to the state range from $40 million to $206 million, depending on the program activity level. All scenarios constructed for the study are cost-effective under the base energy cost scenario.

Figure E-1
Net Avoided-Cost Benefits of Commercial Natural Gas Efficiency Savings—2003 to 2012



This report is one of a series examining energy-efficiency potential in the major IOU service territories. Other reports in the series address energy-efficiency potential in additional sectors, such as residential and industrial as well as commercial electric efficiency potential. All reports in this series will be available for download from www.calmac.org.

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, the fewer power plants and less fuel consumption 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.

E.2 STUDY SCOPE

This study focuses on assessing natural gas energy-efficiency potential in the commercial sector existing construction market for the major IOUs. This market includes both retrofit and replace-on-burnout measures, and thus 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, 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.

E.3 STUDY CONTEXT

E.3.1 California Natural Gas Use

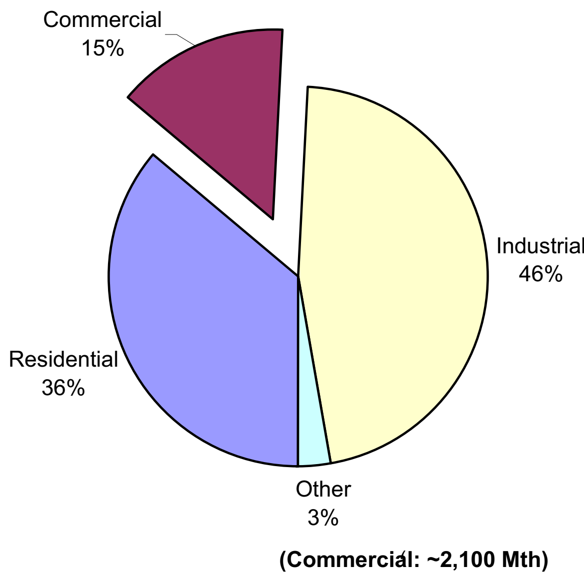
To understand and estimate the potential for further efficiency improvements in California's natural gas use, it is important to understand how natural gas is used in the state. Baseline data presented here and throughout this report are based on sector and end-use data from 2000, the latest detailed California Energy Commission data available at the time this study was initiated. Thus, these figures do not account for the conservation-based reductions that occurred in 2001

The major categories of end use natural gas consumption in California are the residential, commercial, and industrial sectors. The commercial sector makes up about 15 percent of the total state end use demand (see Figure E-2), using about 2,100 Mth per year. Note that end use consumption excludes natural gas used in the production of electricity.

Commercial natural gas consumption by end use is shown in Figure E-3. Water heating and space heating are by far the largest users of natural gas, accounting for 38 percent (782 Mth) and 31 percent (643 Mth) of total commercial consumption respectively. Cooking is the next largest end use, accounting for about 22 percent of total consumption.

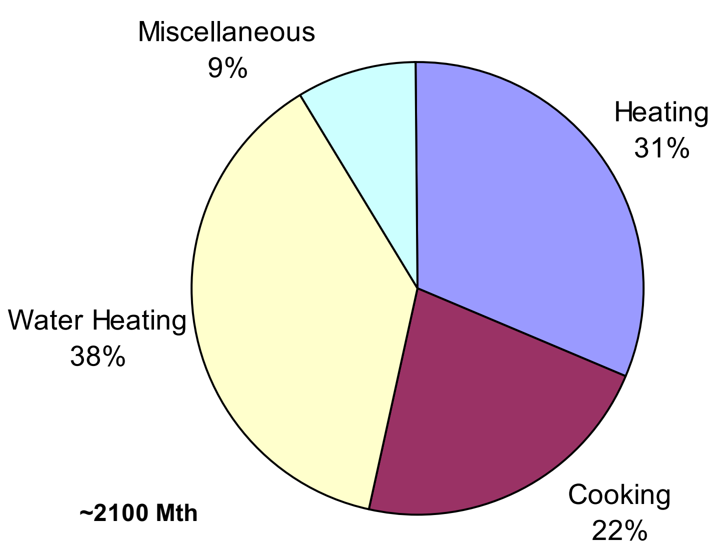
Restaurants account for the largest share of commercial natural gas usage in the state, at around 22 percent, or roughly 460 Mth. The next highest energy-consuming segments in the commercial sector are miscellaneous buildings, offices, and hospital/health facilities, each accounting for between 10 and 16 percent of commercial usage.

Figure E-2
Contribution of the Commercial Sector to California Natural Gas Use



Source: CEC 2000. *California Energy Demand: 2000-2010.*
Excludes natural gas used for electric production

Figure E-3
Breakdown of Commercial Natural Gas Use by End Use



Source: PG&E, SCG, and SDG&E CEUS and XENERGY analysis.

E.4 PROGRAM POTENTIAL RESULTS – 2002 TO 2011

To help decision-makers balance energy efficiency with competing priorities, it is useful to develop scenarios that represent different levels of program activity. For this study, we used four different commercial sector energy-efficiency scenarios reflecting different levels of funding for program activity. The scenarios were originally developed for the Commercial Electric Energy Efficiency Potential Study, and then extended to this companion report, which addresses commercial natural gas energy efficiency potential.

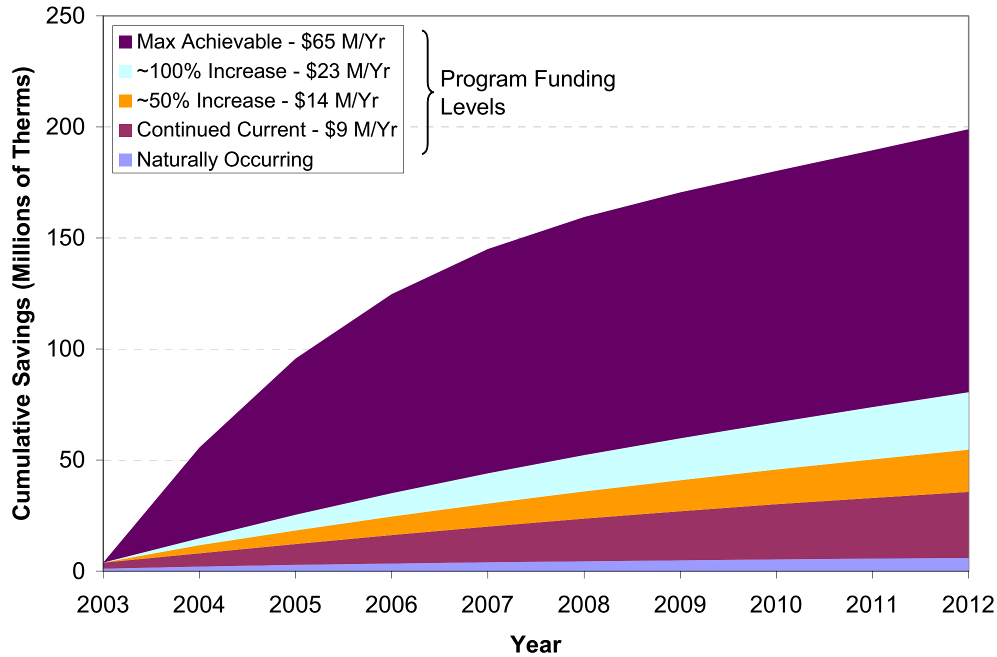
The first scenario is "Continued Current," which is intended to approximate a continuation of the current (2002) program activity level over the next 10 years. The next two scenarios, "50% Increase" and "100% Increase," represent roughly 50-percent and 100-percent increases in total program activity as compared to the "Continued Current" case, over 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 were made fully aware and knowledgeable of efficiency measures and all incremental costs were paid for by the program. The level of program effort in this scenario is roughly 600 percent higher than under the "Continued Current" case.

E.4.1 Program Potentials—Energy Impacts

We forecasted program energy savings under each funding scenario for a 10-year period beginning in 2003. Our estimated energy program potentials are shown in Figure E-4. Net program energy savings potential ranges from roughly 30 Mth under the "Continued Current" scenario to almost 200 Mth under the "Max Achievable" scenario. Under the "Continued Current" scenario, roughly 7 percent of our estimated economic potential[1] of 430 Mth would be captured. Under the "Max Achievable" scenario, we estimate that 45 percent of the economic potential (193 Mth) could be captured. Estimated energy savings under the "50% Increase" and "100% Increase" scenarios are approximately 49 and 75 Mth, respectively.

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

Figure E-4
Program Natural Gas Savings Potential by Funding Level

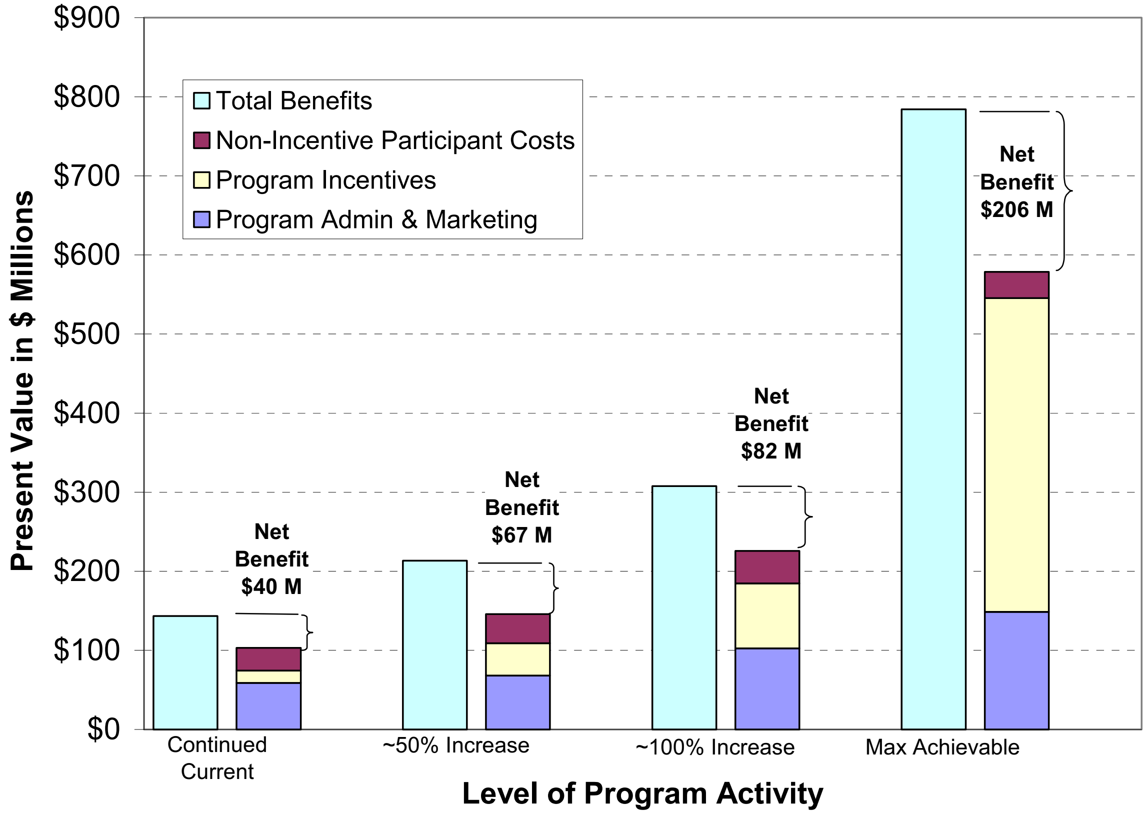


E.4.2 Program Potentials—Benefits and Costs

The costs and benefits associated with the commercial efficiency scenarios over the 10-year period are summarized in Figure E-5. As shown in the figure, total program funding varies from $74 million under the "Continued Current" scenario, to $109 million under "50% Increase," to $185 million under "100% Increase," to $545 million under "Max Achievable." Total avoided-cost benefits range from $143 million under "Continued Current" to $784 million under "Max Achievable." Net avoided-cost benefits, which are the difference between total avoided-cost benefits and total resource costs (which include participant's costs), range from $40 million to just over $200 million. All of the scenarios are cost-effective based on the total resource cost test, which is the principal test used in California to determine program cost effectiveness:

Program Activity Scenario	Benefit-Cost Ratio
"Continued Current"	1.4
"50% Increase"	1.5
"100% Increase"	1.4
"Max Achievable"	1.4

Figure E-5
Costs and Benefits of Commercial Natural Gas Efficiency Savings – 2003 to 2012*



*Note: Participant costs less incentives account for the difference between program costs and total resource costs.

E.4.3 Program Potentials Under High and Low Energy Costs Scenarios

The preceding results are based on a base-case forecast of retail natural gas 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 California Public Utilities Commission for use in the IOUs' 2001 program cost-effectiveness analyses. The base retail rate forecast is benched to the actual 2002 average rate and escalated at the same rate of change as the avoided-cost forecast. In recognition of the considerable uncertainty in both future retail and wholesale natural gas costs, we constructed two alternative energy cost scenarios. One scenario captures a lower cost future and the other a higher cost future.

Estimates of net program potentials under Low energy costs are roughly one-third of those estimated under the Base energy costs. Net program potentials under the High scenario are somewhat higher as those under the Base energy costs because customers will tend to install many gas savings measures anyway without the programs (a phenomenon referred to as naturally occurring savings).

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

These findings represent a critical first step in the process of understanding the resource potential of energy efficiency in the commercial sector. However, they are based on static avoided-cost forecasts, which do not provide sufficient information for determining the optimal mix of all possible resources (e.g., energy efficiency, demand response/curtailment, increased gas storage, conventional supply, renewable energy, etc.).

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 stated in Section 1, the scope of this report focused on the retrofit of existing buildings. 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.

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 that would explicitly tackle the question of 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 off of 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 natural gas energy-efficiency potential in existing commercial buildings within the service territories of the three major investor-owned gas utilities in California: Pacific Gas and Electric Company (PG&E), Southern California Gas Company (SCG), and San Diego Gas and Electric Company (SDG&E); 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 on gas savings potential in existing commercial buildings is one in a series on energy-efficiency potential in the major IOU service territories. Each study is designed as a stand-alone piece 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 additional sectors and vintages, including industrial electric, commercial electric, residential gas and electric, and new construction efficiency potential.

This report provides both detailed and aggregated estimates of the costs and savings potential of natural gas energy-efficiency measures for existing commercial buildings.[1] In addition, forecasts are developed 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 natural gas rates and wholesale natural gas 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 a 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 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

[1] This report excludes potential from commercial new construction, which will be addressed in a forthcoming report.

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 natural gas 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 natural gas energy-efficiency potential in the existing construction market of the commercial sector within the territories of the major IOUs. This market includes both retrofit and replace-on-burnout measures, and thus it explicitly excludes new construction and major renovation markets (new construction will be addressed in subsequent studies). 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 near-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 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 in future studies.

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 or gas price spikes 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 resulting from the recent energy crisis.

1.4 ENERGY EFFICIENCY AS A ENERGY "RESOURCE"

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, Arthur Rosenfeld,[2] Roger Sant,[3] Amory Lovins (Lovins et al. 1986), and Alan Meier (Meier 1982), 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. In the early 1980s 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. 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.[4] 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. 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.

Somewhat analogously, 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.

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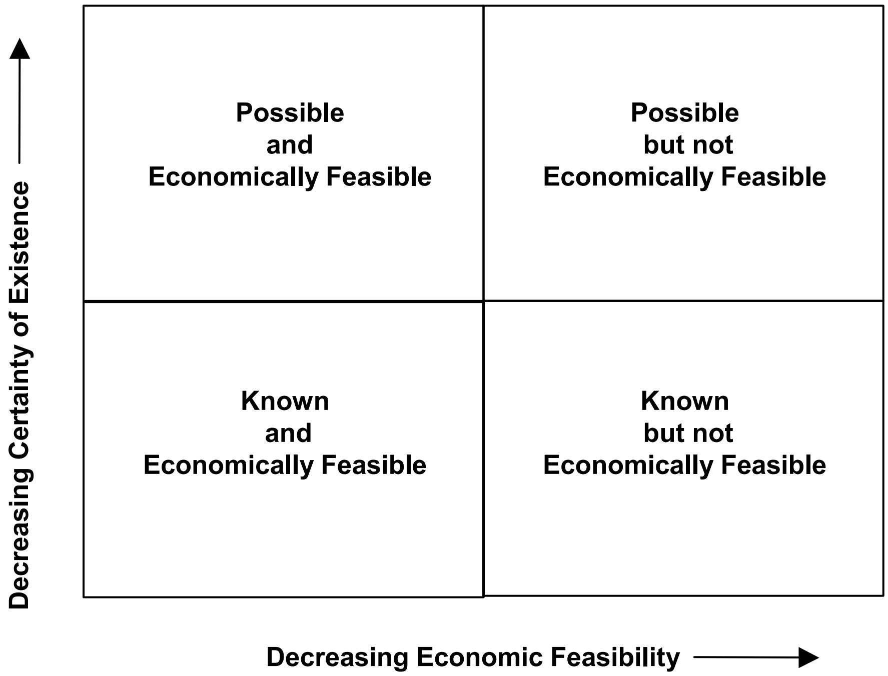
[2] Rosenfeld provides an excellent and interesting historical summary of the early days of developing estimates of energy-efficiency potential, beginning in the 1970s, in Rosenfeld 1999.
[3] Sant is often credited with coining the terms "least cost energy services" and "cost of conserved energy."
[4] Energy-efficiency supply curves are described in more detail later in this section.

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



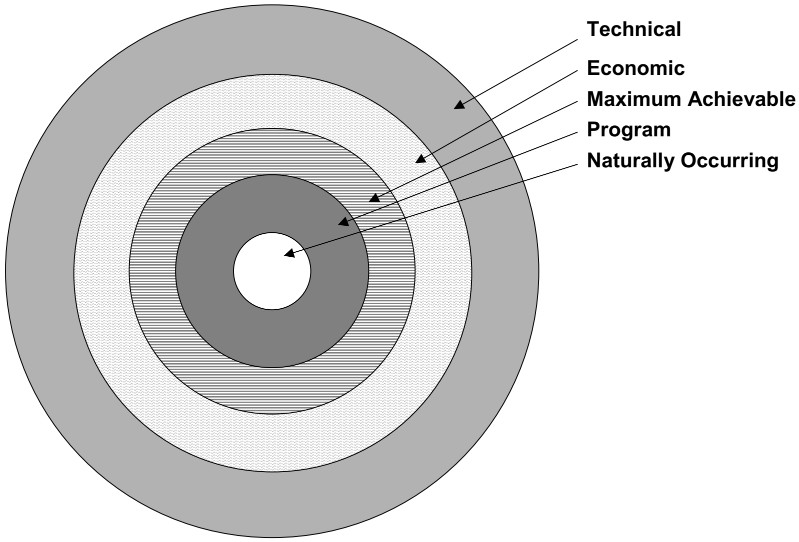
Source: Healy et al. 1983.

The first set of energy-efficiency potential studies focused primarily on identifying what is often called technical potential. **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.

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.[5] 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.

[5] 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.

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



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.[6] 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 additional expenditures for administration and marketing beyond the costs of the measures themselves. These added program costs reduce the amount of potential that it is economic to acquire.

Although the potentials defined above are important and helpful for establishing the amount of the efficiency resource that is theoretically available, utility resource planners and government 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

[6] 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.

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 we and others 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 natural gas use;
- Section 3 summarizes historic energy-efficiency expenditures and savings;
- 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;
- Section 7 presents program potential results;
- Section 8 discusses issues associated with the study results and next steps for further research; and
- Section 9 lists sources used in 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
- Appendix D – Floor Space and Time-of-Use Inputs (square footage and load shapes)
- Appendix E – Non-Additive Measure-Level Results
- Appendix F – Segment and End Use Summary Program Potential Results
- Appendix G – Achievable Program Scenarios
- Appendix H – Summary of PY2001 Commercial IOU Programs
- Appendix I – DSM ASSYST Model Documentation

2 STUDY CONTEXT: NATURAL GAS USE IN CALIFORNIA

This section provides background data and discussion on natural gas use in California. We begin by presenting historical use for the State as a whole and then focus on characterizing commercial use within the major investor-owned utilities (IOUs). Our analysis of baseline consumption focuses on the year 2002, and as most readers are aware, 2001 was an unusual year with respect to energy consumption because of the massive conservation response to the 2001 energy crisis. In addition, natural gas prices spiked dramatically in 2001.

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 natural gas use is strongly correlated with population and economic growth, the State's natural gas use has also increased over the past 40 years.

2.1 RECENT OVERALL USE AND PAST TRENDS

California is the second largest consumer of natural gas in the nation, second only to Texas. Table 2-1 shows California end use natural gas consumption from 1980 through 2000. In the 1980s end use natural gas consumption statewide dropped by an average of 1.5 percent annually, followed by an average 2.5 increase annually in the 1990s. In 1998, the last year for which comprehensive historic data is available, statewide end use gas consumption was 14,344 millions of therms (Mth).[2]

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

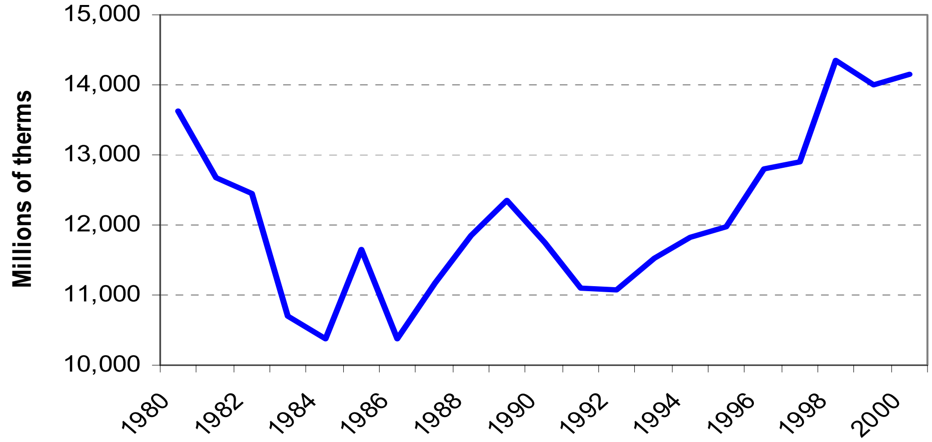
The major categories of end use natural gas consumption in California are the residential, commercial, and industrial sectors.[3] Figure 2-2 shows that the commercial sector gas use has remained relatively steady over the years.

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

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

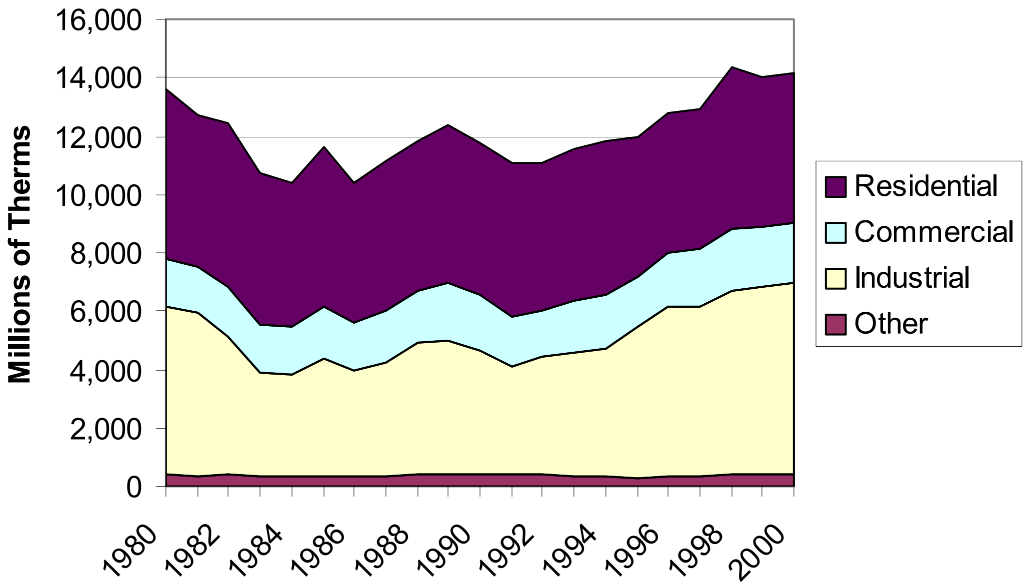
[3] End use consumption figures exclude natural gas used in the production of electricity, whether that gas is used by power plants or by cogeneration facilities. Natural gas usage for generation accounts for 20 percent of the total gas consumption as compared to roughly 80 percent for the residential, commercial, and industrial sectors.

Figure 2-1
California Natural Gas Consumption: 1980 – 2000



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

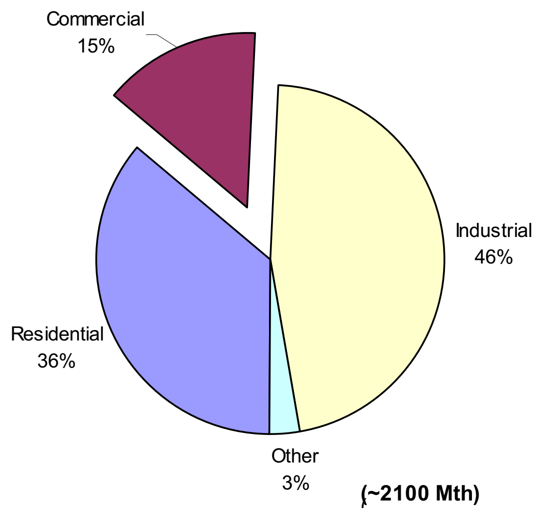
Figure 2-2
California Natural Gas Consumption by Sector: 1980 – 2000*



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

Figure 2-3 shows the breakdown of consumption by sector in 2000; the commercial sector represented 15 percent of the State's usage, while the industrial sector represented the largest share of recent gas consumption, representing 46 percent, followed by the residential sector at 36 percent.

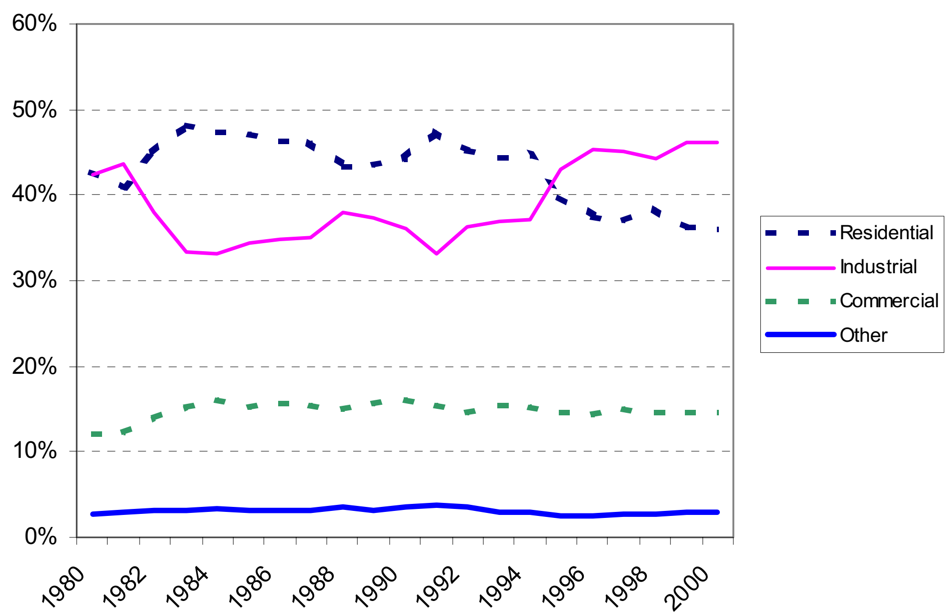
Figure 2-3
Breakdown of California Natural Gas Use by Sector



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

As shown in Figure 2-4, 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 has remained relatively constant, averaging approximately 16 percent.[4]

Figure 2-4
Trends Natural Gas Consumption by Sector: 1980 – 2000*



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

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

2.2 IN-SCOPE COMMERCIAL SECTOR NATURAL GAS USE

The scope of this study includes commercial natural gas consumption in the territories of the State's three major gas IOUs: Pacific Gas & Electric (PG&E), Southern California Gas (SCG), and San Diego Gas & Electric (SDG&E). The gas IOUs account for 99 percent of the State's total natural gas consumption. Therefore, this report uses statewide figures for gas.

Commercial customers within the service territories of the major IOUs accounted for approximately 2,100 Mth in 2000, representing about 15 percent of the total gas consumption in the State, which was estimated over 14,000 Mth in 2000.[5]

Figure 2-5 illustrates the trend of commercial gas use per square foot. Historical data is used up to 1998. As is clear from the figure, the overall trend for California's gas intensity use is decreasing from usage levels in the 1980s.

Figure 2-5
Commercial Natural Gas Consumption
(Therms per Square Foot)

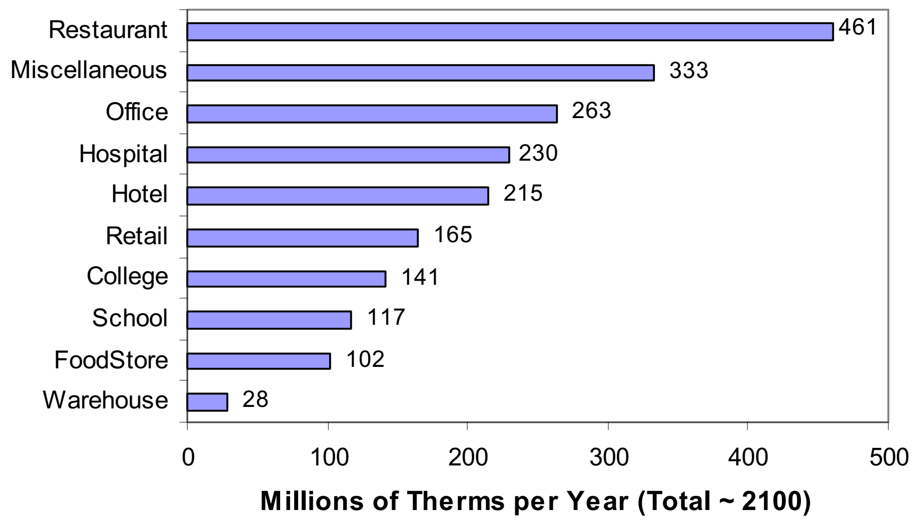
Source: CEC 2000. *California Energy Demand*

Natural gas consumption within the commercial sector can be analyzed in a variety of ways. In Figure 2-6, we summarize the characteristics of commercial natural gas consumption. Restaurants account for the largest share of natural gas usage at around 22 percent, or roughly 461 Mth. The next largest gas-consuming building types were miscellaneous buildings (such as

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

auto repair shops, health clubs, movie theaters, and museums), accounting for about 16 percent of commercial usage or about 333 Mth.

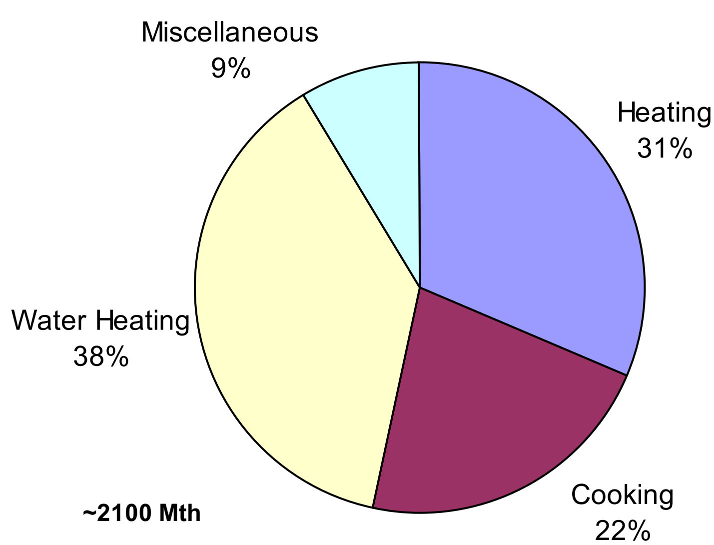
Figure 2-6
Commercial Natural Gas Usage by Building Type within the Major IOU territories



Source: PG&E, SCE, and SDG&E CEUS and XENERGY analysis.

Commercial natural gas consumption by end use is shown in Figure 2-7. Water heating and space heating are by far the largest users of natural gas, accounting for 38 percent (782 Mth) and 31 percent (643 Mth) of total commercial consumption respectively. Cooking is the next largest end use, accounting for about 22 percent of total consumption.

Figure 2-7
Commercial Natural Gas End-Use Breakdown for Major IOUs

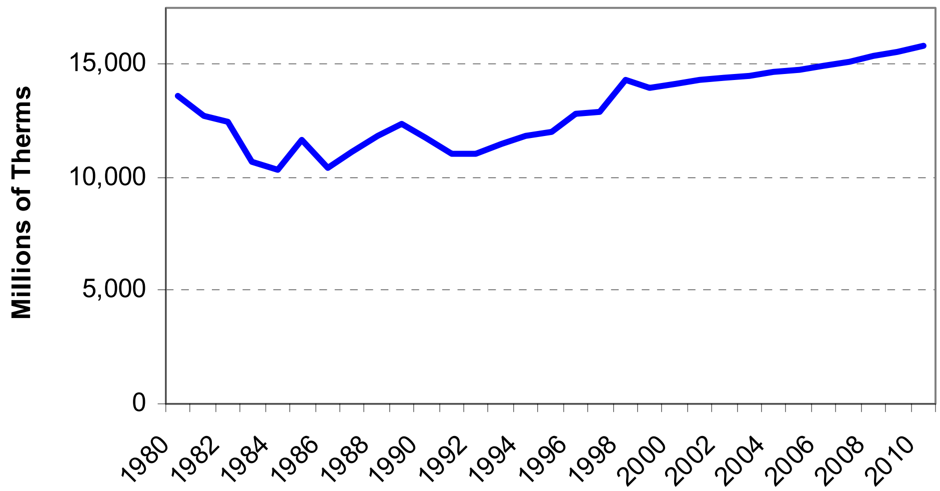


Source: PG&E, SCE, and SDG&E CEUS and XENERGY analysis.

2.3 CEC Forecasts of Future 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 California Energy Commission (CEC). Note that the historic forecasts assume normal weather and economic conditions. Actual consumption in any given year can vary considerably in response to these to conditions. Figure 2-8 shows the CEC's forecasted gas consumption statewide through 2010.

Figure 2-8
CEC End Use Gas Consumption Forecasts through 2010*



*Historic data through 1998. Source: CEC 2000. *California Energy Demand: 2000-2010. Figures do not include gas used for electricity production.*

End Use natural gas consumption in 1998 was 14,344 Mth, which is the last year for which complete historical data is 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.

3 ENERGY EFFICIENCY PROGRAMS

This section presents information on California's natural gas energy-efficiency programs. It provides historic information on all natural gas programs but focuses primarily on the major IOUs' commercial sector programs. 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.

Natural gas 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 lowering a thermostat setting from 70 to 65 ^{o}F for heating. As a result of the availability of gains from efficiency and conservation, the relationship between economic growth and energy use is far from constant.

3.1 CALIFORNIA NATURAL GAS 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 both electricity and natural gas are used. Spending on programs, however, has increased and decreased, sometimes dramatically, over time. Some of the key milestones and trends in the 25-year history of efficiency programs in the State include the following:

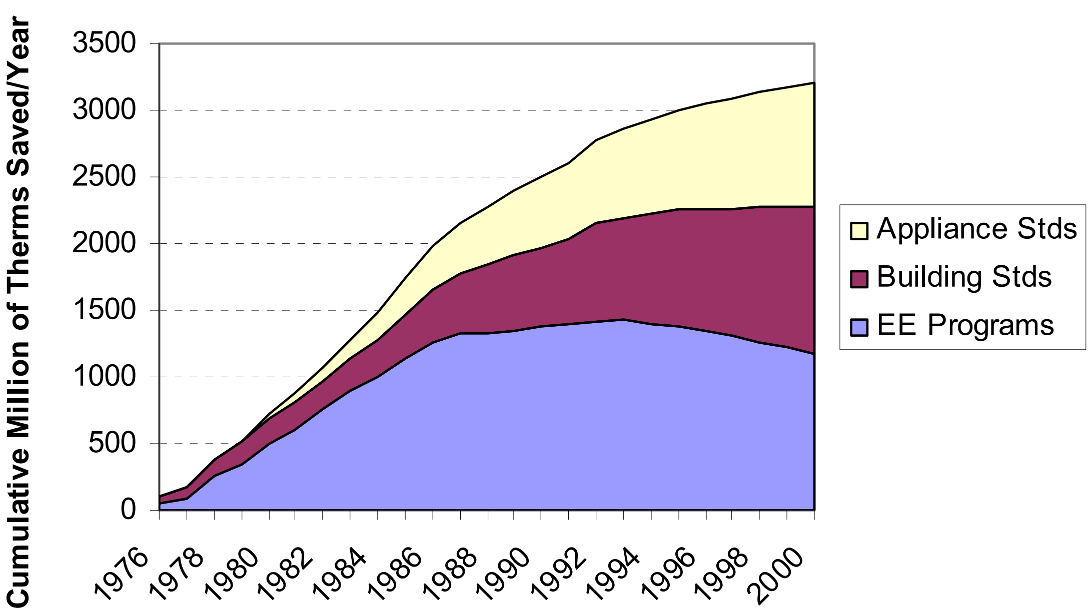
- In the mid-1970s, the State, through the California Energy Commission, developed comprehensive energy codes to require that new residential and commercial buildings and appliances meet minimum energy-efficiency standards. The CEC subsequently worked on 3-year cycles to continuously review and upgrade building standards.
- 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 for both electricity and natural gas-oriented programs.

- 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 some 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.

As stated in a milestone above, 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. Savings from efficiency programs, run primarily by utilities, vary over time primarily as a function of program expenditure levels. As shown in Figure 3-1, natural gas savings from programs and standards were on average approximately 2,000 million therms (Mth) per year through the year 2000. Savings from energy-efficiency programs accounted for roughly half of the impacts overall.

Figure 3-1
Natural Gas Savings Impacts of Energy-Efficiency Programs and Standards*

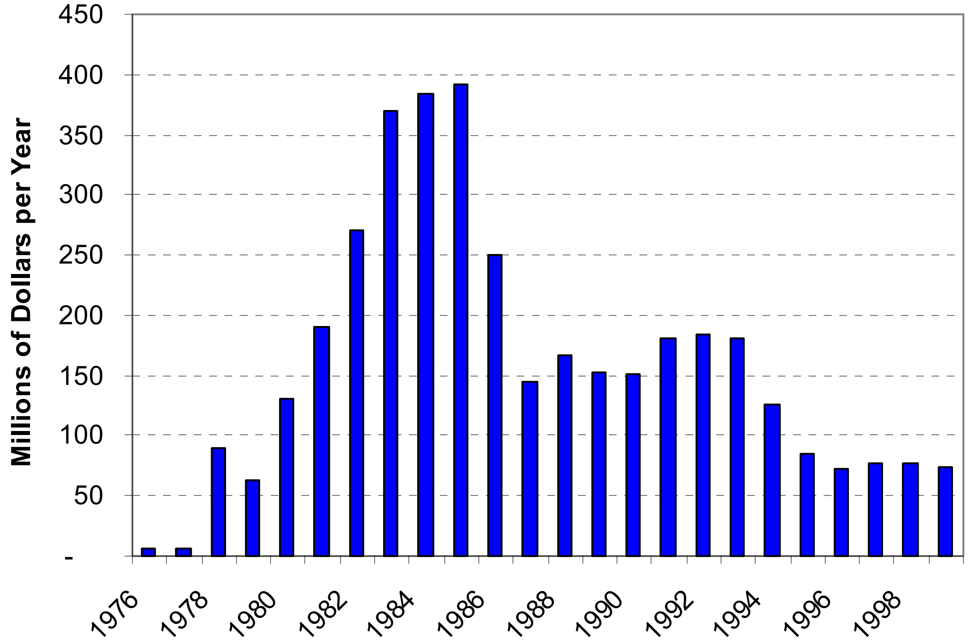


* Historic data through 1998. Source: California Energy Commission (CEC) 2000. *California Energy Demand: 2000-2010*. P200-00-002.

Savings from energy-efficiency programs have varied widely throughout the past 25 years as a function of changes in annual funding levels. As shown in Figure 3-2, spending levels peaked in

1985, while expenditure downturns and valleys 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.[1] These funding swings have reflected changes in policymakers' perceptions about energy prices, as well as philosophical shifts in the State's political and regulatory orientation.

Figure 3-2
Annual Natural Gas Energy-Efficiency Program Expenditures for Major IOUs (in current dollars)

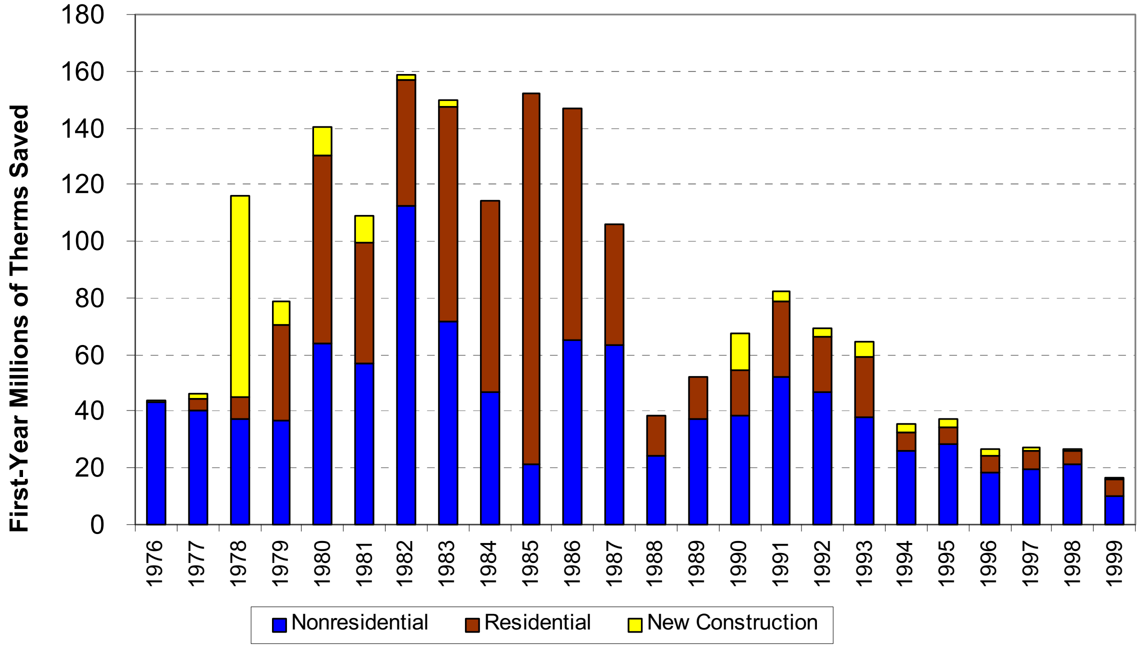


Source: Historic data compiled by CEC staff. Smith 2002.

Annual program impacts for major IOU natural gas efficiency programs are shown in Figure 3-3. The pattern of energy savings over time generally follows expenditure levels. First-year energy savings (savings achieved by the program in that year) peak at 159 Mth in 1982, but first-year savings have tended to average around 79 Mth. Nonresidential (commercial and industrial) program savings have accounted for an average of 60 percent of natural gas savings historically, but represented closer to 72 percent of savings in recent years. Residential and new construction sector savings accounted for approximately 40 percent of the savings achieved.

[1] Data were not yet available after 1999.

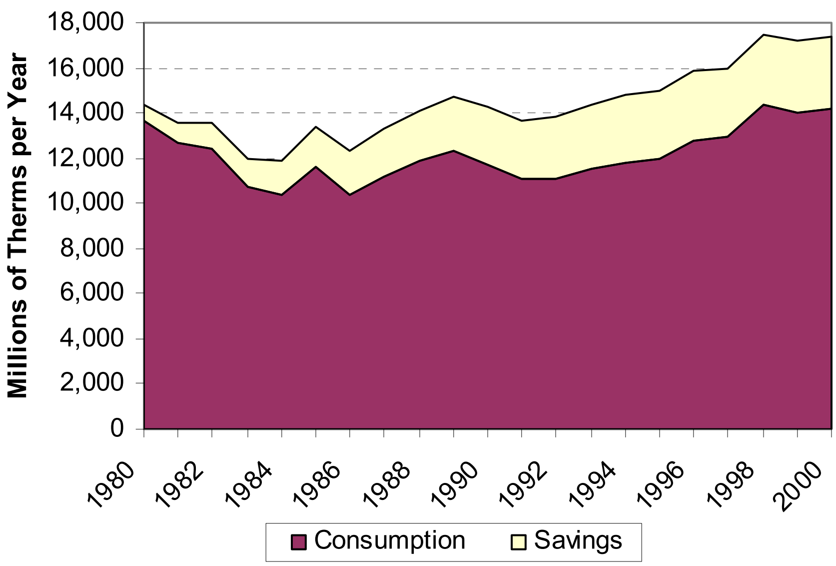
Figure 3-3
First-Year Natural Gas Savings for Major IOUs' Efficiency Programs*



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

The cumulative effect of California's efficiency programs and standards is shown in relation to actual natural gas consumption over the past 25 years in Figure 3-4. Savings as a proportion of consumption has remained fairly constant over time.

Figure 3-4
Cumulative Impact of California Efficiency Programs and Standards*



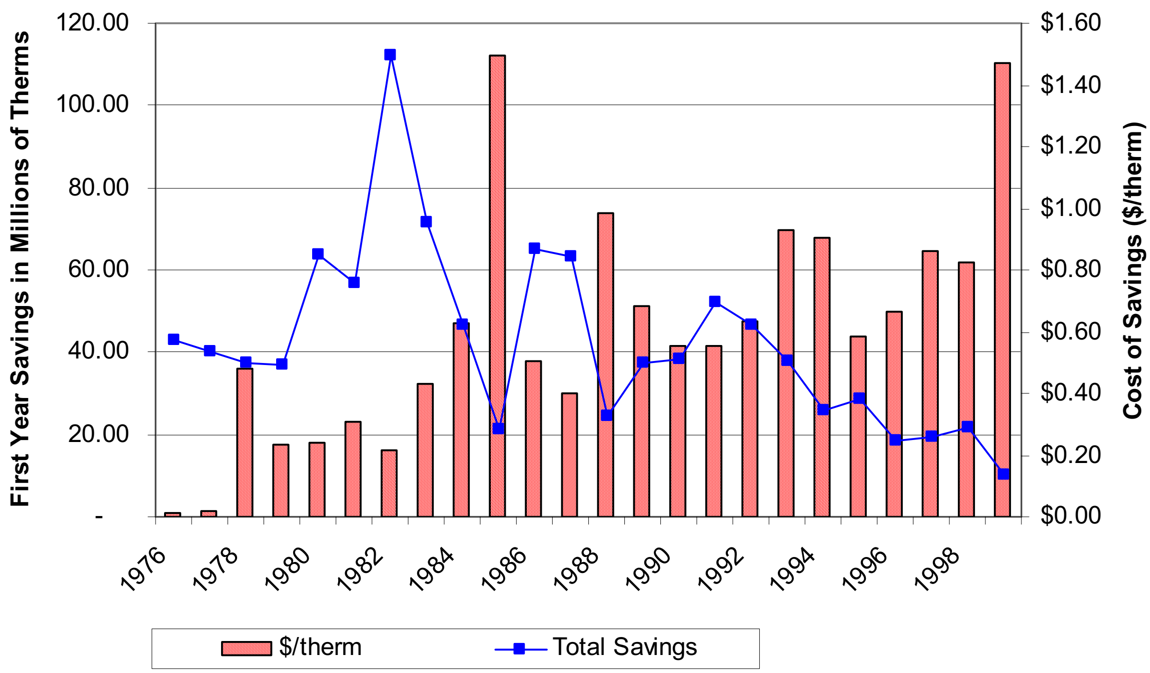
* Historic data through 1998. Source: California Energy Commission (CEC) 2000. *California Energy Demand: 2000-2010*. P200-00-002.

3.2 MAJOR NONRESIDENTIAL IOUS' PROGRAM IMPACTS: 1980 — 2000

Because the focus of this report is on natural gas energy-efficiency potential in the commercial sector of the major IOUs, in this subsection we present summary data on the impacts of the major IOUs' nonresidential energy-efficiency programs for all sectors over the period 1980 to 1999 (data was not yet available for subsequent years). The data reported in this subsection should be considered a rough estimate, rather than a definitive reporting, and is included in order to provide the appropriate context for the results presented in later sections. This data should not be considered a definitive reporting of natural gas savings and program dollars for several reasons. Data gathered by the California Energy Commission does not segregate the gas savings and the program dollars for the nonresidential sector into industrial and commercial components. In addition, utility reporting is not consistent over the years and is not consistent across utilities due to changes in reporting requirements. This limits the ability to aggregate numbers for statewide figures and hinders the ability to appropriately compare data across years.

The Figure 3-5 illustrates the combined long-term natural gas energy-efficiency program activity among the major IOUs. This figure shows the total net savings as well as the administrative expenditures per unit of savings in the nonresidential sector from 1980 through 1999.

Figure 3-5
Natural Gas Nonresidential Energy-Efficiency Savings and Expenditures
(in current dollars per *first-year* therm saved)



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

In general, the statewide trend from the 1976 through 1982 for gas savings through energy-efficiency programs was toward increasing annual savings, peaking at 112 Mth in 1982. These increases occurred as a reaction to the first and second oil price shocks. The savings tapered dramatically from 1982 to 1986. Funding and savings decreased rapidly up until the present, while program costs per unit of savings increased (with some exceptions in 1986-1987 and 1989-1991, where savings increased). The decline in savings reflects the effects of increased building and equipment standards, technical constraints on increased gas efficiency, and changes in reporting requirements.

The average program cost[2] per unit of savings climbed from 1976 through 1985. Since 1988, there has been a gradual upward trend of program cost per unit of savings. In 1999, program cost per unit of savings increased significantly. In 1998, many programs were changed in response to orders from the California Board for Energy Efficiency (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 gas savings continued to decline. Again, this decline may be explained in part by changes in reporting requirements.

3.3 SUMMARY OF PY2002 PROGRAMS

This subsection briefly summarizes recent nonresidential program activities for natural gas administered by the major IOUs.[3] A more complete summary of recent program activity is provided in Appendix H.

Common Programs Across IOUs

For the most part, the major statewide nonresidential programs offered by the four IOUs that addressed natural gas common in 2002 also addressed electricity. These programs included the following (approximate original budgets for 2002 for the natural gas portion of the program are provided in parentheses and include all four major IOUs unless otherwise noted):

- Standard Performance Contract (SPC) ($1.73 million statewide incentive budget; this represents SDG&E and PG&E incentive budgets only, as there were no gas SPC incentives offered in SCE or SCG territory) provides financial incentives for installation of energy-efficient equipment, such high-efficiency boilers and domestic water heaters
- Express Efficiency ($1.9 million statewide incentive budget; this represents PG&E, SCG and SDG&E, as SCE did not provide Express gas incentives) provides standardized rebates for installation of specific energy-efficiency measures and is targeted to small- and medium-sized customers, such as water boilers and insulation
- Energy Audit Programs ($3.95 million statewide direct implementation[4] budget for natural gas and electrical audits) provide customers with site-specific energy-

[2] 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.
[3] Nonresidential energy-efficiency program information was developed through a review of utility filings, PY2001 1st Quarterly Reports, and program manager interviews.

efficiency information, mostly targeted to commercial customers, such as high-efficiency boilers and flue gas recovery

- Building Operator Certification and Training Program ($608,125 statewide direct implementation budget) seeks to train operators of medium and large commercial buildings to identify and implement energy savings opportunities as an integral part of their operations and maintenance activities. The curriculum includes facility operations and maintenance; heating, ventilation, and air conditioning; energy management systems and more.

As noted, most of the programs and associated funding involves payment of incentives to promote installation of energy-efficient equipment. Important exceptions are the Audit and Building Operator Certification and Training programs, which provide services directly to end use customers without the use of incentives.

Information, Outreach, and Technical Support

The major IOUs also provided various types of energy-efficiency support activities such as:

- Business energy guides designed to help small nonresidential customers better manage their energy costs through energy efficiency
- Energy centers designed to educate customers about energy-efficient business solutions
- Emerging technologies activities that focus on demonstrating energy-efficiency options not widely adopted by various market actors
- Renovation and remodeling programs that encourage high-performance nonresidential building design and construction practices.

Much of the noted support activities target the commercial sector. However, the emerging technologies and renovation and remodeling areas also support energy efficiency in the industrial sector.

Other Support and Programs

Each of the major IOUs also offered a number of programs designed to support the financial incentives programs (e.g., Express Efficiency, SPC). These programs include such activities as providing special services to upstream market actors such as technical assistance, incentives, etc., targeting more complex applications and/or providing marketing and outreach support to target market segments such as the hard to reach. The commercial sector is the primary focus for most of these programs.

[4] In cases were programs do not provide incentives to customers, we have used the direct implementation budgets instead. Direct implementation figures account for services provided directly to customers and do not include marketing or administrative costs.

The utilities also contract for a number of Third-Party Initiative and Summer Initiative programs. For the most part, these programs also primarily target the commercial sector. (Appendix H provides a list of these third-party programs for 2001).

4 METHODS

4.1 OVERVIEW

This section describes the methods used to conduct this study; it explains the specific steps and methods employed at each stage of the analytical process necessary to produce the results presented in Sections 6 and 7 of this report.

4.2 SUMMARY OF ANALYTICAL STEPS USED IN THIS STUDY

This study involves carrying out a number of basic analytical steps to produce estimates of the energy-efficiency potentials. 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 model used, DSM ASSYST│, is an MS-Excel-based model that 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 J.

The steps implemented in this study are listed below, each of which is described in the remainder of this section:

Step 1: Develop Initial Input Data

- Develop a list of energy-efficiency measure opportunities
- Gather and develop technical data (costs and savings) on efficient measure opportunities
- Gather, analyze, and develop information on building characteristics, including total square footage, end-use consumption, market shares of key natural-gas-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 natural gas prices and current and forecasted costs of natural gas fuel, along with estimates of other potential benefits of reducing supply, such as the value of reducing environmental impacts

- 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.

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.

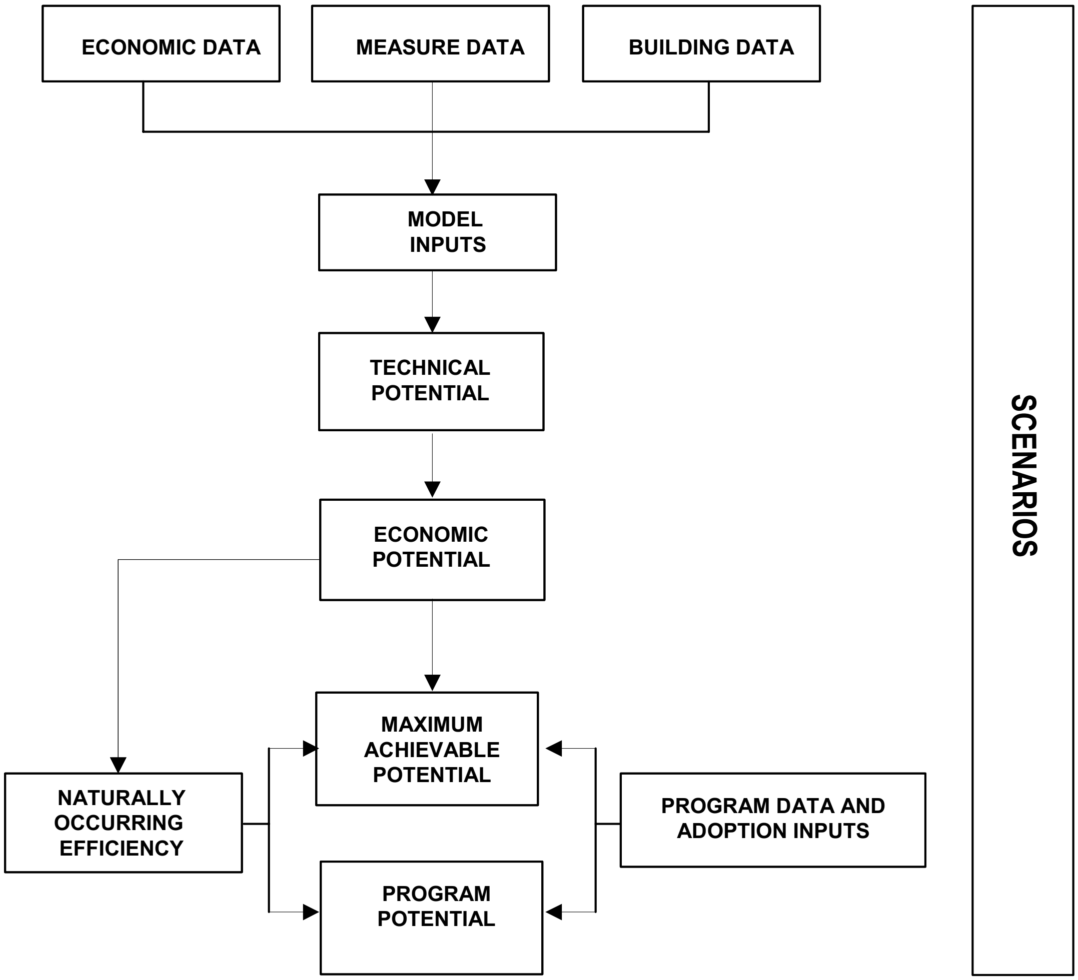
4.3 STEP 1: DEVELOP INITIAL INPUT DATA

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 study is shown in Table 4-1. The study scope was restricted to energy-efficiency measures and practices that are presently commercially available. These are measures that 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, this study 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.

In our prior study of the commercial building sector electricity efficiency potential, it was possible to develop an initial list of efficiency measures from the *DEER Update 2001 Study* (XENERGY 2001c). In this gas study, we used a combination of sources that included DEER, utility program filings, and other secondary sources. To supplement the DEER Study data, we compiled and reviewed several other sources. Primary sources included the Pacific Gas & Electric (PG&E), Southern California Gas (SCG), and San Diego Gas & Electric (SDG&E) PY2002 program information and filings and prior-year program materials. Another key source was the *Conservation Potential Study* conducted by XENERGY for SCG in 1992 (XENERGY 1992b). We also identified and reviewed other sources of information on gas measures including publications from the Federal Energy Management Program, industry organizations, and others.

Figure 4-1
Conceptual Overview of Study Process



After developing an initial measure list, we developed measure characteristics data for as many of the measures as possible. In some cases, inadequate data was available for critical inputs such as incremental costs, savings, or base-case equipment saturation. Measures for which inadequate data was available were dropped from the final measure list.

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. Much 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 for 2001, as well as other secondary sources.

Table 4-1
Measures Included in Scope of Commercial Gas Potential Study

End Use	Energy-Efficiency Measures
Heating	Ceiling insulation (In situ R5 to R24), double-pane low emissivity windows, duct insulation installed, duct leakage repair, high-efficiency (power burner/ premium) furnace/boiler 95% efficiency (in situ base=82%), boiler- heating pipe insulation, boiler tune-up, EMS install, EMS optimization, stack heat exchanger, heat recovery from air to air, heat recovery from AC
Water Heating	Eff gas water heater system 95% efficiency (base=76%), instantaneous water heater <=200 MBTUH, circulation pump time clocks retrofit system 7 day time clock, tank insulation, pipe insulation, low-flow showerheads, faucet aerator, solar DHW system active
Cooking	High-efficiency appliances, infrared appliances, power burner appliances, convection oven, and electric controls
Pool Heating	High-efficiency pool heater, pool cover, and solar water heater (includes pools in commercial settings, such as health clubs and hotels; does not include multi-family common areas)

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 California Conservation Inventory Group's *Technology Energy Savings Study* (NEOS 1994)
- IOU energy-efficiency program applications to the CPUC
- Secondary sources.

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

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. A variety of data are needed to estimate the average and total savings potential for individual measures across the entire existing commercial building population. The key data needed for our representation of the population of existing buildings included:

- Total gas-served floor space of the in-scope commercial buildings
- Annual natural gas consumption for each end use studied (both in terms of total consumption in therms and normalized for intensity on per-square-foot basis, i.e., therms/ft^2)
- The saturation of natural gas end uses (for example, the fraction of total commercial floor space with natural gas water heating [boiler, tank, or instantaneous])

- The market share of each base equipment type (for example, the fraction of total commercial floor space served by natural gas domestic hot water heaters)
- Market share for each energy-efficiency measure in scope (for example, the fraction of total commercial floor space already served by high-efficiency boilers).

Most of the data elements listed above were required at the utility service area and building type level for this study. These key data elements are discussed briefly in the following subsections. More detailed documentation is provided in Appendices A through D.

Floor Space and End-Use Natural Gas Consumption

The primary source of floor space was the California Energy Commission (CEC) commercial end-use forecasting database. The primary sources for the end-use energy consumption estimates were the PG&E and SDG&E Commercial End Use Studies (CEUS) (PG&E 1999; SDG&E 1999). In the end-use forecasting approach, end-use natural gas consumption is expressed as the product of building floor space (in square feet), the fraction of floor space associated with a given end-use fuel (the end-use fuel saturation), and the EUI (the energy-use intensity of an end use expressed in therms per square foot). These three data elements have been collected and estimated from various sources over time and form the foundation upon which the CEC natural gas forecasts are developed. However, we did not deem as reliable the CEC's end-use estimates for the purposes of this study (in contrast to the CEC's end-use electric data, which we have deemed as reliable for both the commercial electric potential study and the residential electric and natural gas studies). We relied more heavily on the CEUS data than the CEC data for our baseline natural gas end-use consumption and intensity estimates. The base gas consumption estimates are shown in Section 2. Additional discussion of the issues associated with these data is provided in Appendix A. Square footage by building type is shown in Appendix D Saturation and EUI data by base equipment type are documented in Appendix C.

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, high-efficiency gas hot water heater measures are only applicable to the portion of the water heater end use that is served by gas water heaters (as opposed to water heating served by gas boilers or electric systems). Inputs 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. The primary sources are the CEUS studies referenced above. These surveys typically involve in-depth collection of building equipment and characteristics data through on-site surveys conducted at representative samples of commercial buildings.

Table 4-2
Data Sources for Technology Shares

End Use	Data Source
Space Heating	PG&E CEUS, SCE CEUS, SDG&E CEUS
Water Heating	PG&E CEUS, SCE CEUS, SDG&E CEUS
Cooking	PG&E CEUS, SCE CEUS, SDG&E CEUS
Pool Heating	PG&E CEUS applied to all three utilities

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

- The PG&E CEUS. Data from this survey were collected by PG&E during calendar years 1996 and 1997 via on-site surveys. A total of 983 buildings were included in the sample. XENERGY analyzed the CEUS data directly to estimate technology shares for this study.
- The Southern California Edison (SCE) CEUS. Data from this survey were collected by SCE via on-site surveys in two waves, based on building type. Data for offices, retail stores, food stores, restaurants, and warehouses were collected in 1992. Data for schools, colleges, hospitals/health facilities, lodging, and miscellaneous buildings were collected in 1995. A total of 700 surveys were conducted in 1992, and 500 surveys were conducted in 1995. The SCE CEUS data includes saturation data for commercial gas equipment.
- SDG&E CEUS. This was a survey of 350 commercial buildings in the SDG&E service territory. Data were collected via on-site surveys during 1998. Extensive technology detail on HVAC systems was available. RER Inc. analyzed the data to provide technology share inputs for this study.

Additional documentation of the base technology shares developed for this study is provided in Appendices A and C.

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 sources of data used for the measure saturation estimates were the utility CEUS studies. In many cases, judgmental adjustments to these saturation estimates were required to bring them up to date because the available sources were several years old. 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 gas savings 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:

Technical Potential of Efficient Measure	=	Total Square Feet	×	Base Case Equipment EUI (therms/ft^2	×	Applicability Factor	×	Not Complete Factor	×	Feasibility Factor	×	Savings Factor

where:

- **Square feet** is the total floor space for all buildings in the market segment.
- **Base case equipment EUI** is the energy used per square foot 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 a high-efficiency boiler, the base EUI would be the annual therms per square foot of an equivalent standard-efficiency boiler.
- **Applicability factor** is the fraction of the floor space that is applicable for the efficient technology in a given market segment, for example, the percentage of hospitals in CEC Forecast Zone 5 with natural gas boilers for heating.
- **Not complete factor** is the fraction of applicable floor space that has not yet been converted to the efficient measure; that is, (1 minus the fraction of floor space that already has the energy-efficiency measure installed).
- **Feasibility factor** is the fraction of the applicable floor space 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.

An example of the core equation is shown in Table 4-3 for the case of a prototypical 75-Watt incandescent lamp, which is replaced by an 18-Watt compact fluorescent in the office segment of the SCE service territory.

Table 4-3
Example of Technical Potential Calculation—Space Heating Boiler Tune-up in the Office Segment of the PG&E Service Territory

Technical Potential of Efficient = Measure	Total Square Feet	Base Case x Equipment EUI (Therms/ft^2)	× Applicability Factor	Not × Complete Factor	× Feasibility Factor	× Savings Factor
0.2 million therms	685 million	0.21	0.28	0.25	1.00	0.02

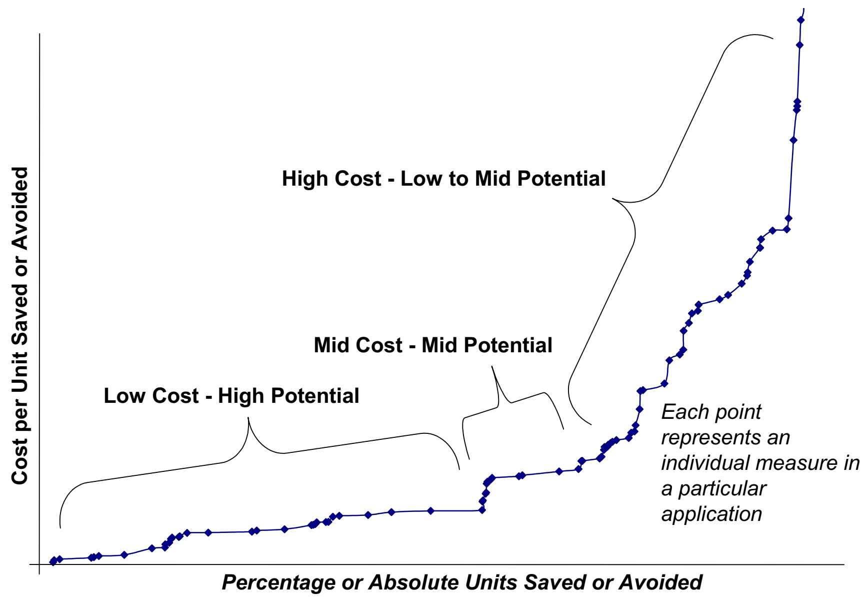
Technical energy-efficiency potential is calculated in two steps. In the first step, all measures are treated independently; that is, the savings of each measure are not marginalized or otherwise adjusted for overlap between competing or synergistic measures. By treating measures independently, their 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. The cumulative savings cannot be estimated by adding the savings from the individual savings estimates because some savings would be double-counted. For example, the savings from a measure that reduces heat loss from a building, such as double-pane windows, are partially dependent on other measures that affect the efficiency of the system being used to heat the building, such as a high-efficiency furnace; the more efficient the furnace, the less energy saved from the application of the double-pane windows.

4.4.2 Use of Supply Curves

In the second step, cumulative technical potential is estimated using an energy-efficiency supply curve approach.[1] 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., dollars per therm saved or dollars per ton of carbon avoided) and another 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., costs increase rapidly and savings decrease significantly at the end of the curve.

[1] 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).

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 therm saved by multiplying the initial investment in an efficient technology or program by the capital recovery rate (CRR):

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

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 Therm Saved = Initial Cost x CRR/Annual Natural Gas Savings

Table 4-4 shows a simplified numeric example of a supply curve calculation for several energy-efficiency measures applied to commercial water heating 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 solar water heating measure shown in Table 4-4 would save more at less cost per unit saved if it were applied to the base-case consumption before the tank insulation and recirculation pump timeclock measures. Because the tank insulation and pump timeclock measures are more cost effective, however, they are applied first, reducing the energy savings potential for the solar system. 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 Mth consumption is recalculated after each measure is implemented, thus reducing the base energy available to be saved by the next measure.

Table 4-4 shows an example that would represent 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 5).

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

Table 4-4
Sample Technical Potential Supply Curve Calculation for Commercial Water Heating
(*Note: Data are illustrative only*)

Measure	Total End Use Consumption of Population (Mth)	Applicable, Not Complete and Feasible Sq.Feet (000s)	Average thm/ft^2 of population	Savings %	Mth Savings	Levelized Cost ($/thm saved)
Base Water Heating	22.9	300,000	0.076	N/A	N/A	N/A
1. Tank Insulation	22.9	230,000	0.076	5%	0.9	$0.06
2. Recirculation Pump Timeclocks	22.0	200,000	0.073	3%	0.4	$0.19
3. Active Solar System	21.6	60,000	0.072	60%	2.6	$0.90
With all measures	19.0		0.063	17%	3.9	

4.5 STEP 3: ESTIMATE ECONOMIC POTENTIAL

As introduced earlier in this section, **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 natural gas fuel costs.

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 debating the merits of different approaches to calculating whether a public purpose investment in energy efficiency is cost effective (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 California Public Utilities Commission (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 test 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 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:[2]

- **TRC 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 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.

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

The key benefits and costs of the various cost-effectiveness tests are summarized in Table 4-5.

Natural gas fuel costs and distribution savings (hereafter, energy benefits) are defined as the economic value of the energy 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.

Table 4-5
Summary of Benefits and Costs of California Standard Practice Manual Tests

Test	Benefits	Costs
TRC Test	Distribution savings (if any) Participants avoided equipment costs (fuel switching only)	Gas fuel 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	Distribution savings (if any)	Gas fuel costs Program costs paid by the administrator Incentives
Ratepayer Impact Measure Test	Distribution savings (if any) Revenue gain	Gas fuel costs Revenue loss Program costs paid by the administrator Incentives

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, 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 furnace), 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 used the TRC test in two ways in this study. First, we developed an estimate of economic potential by calculating the TRC of individual measures and applying the methodology described below. Second, we developed 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). Thus, our definition of economic potential is that portion of the technical potential that passes our economic screening test (described below) exclusive of program costs. Economic potential, like technical potential, is a theoretical quantity that will exceed the amount of potential we estimate to be achievable through current or more aggressive program activities.

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 below.

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

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

where

d= the discount rate
p= the costing period (only one period used for natural gas)
t= time (in years)
n= 20 years

The discount rate used is 8 percent, as required by the CPUC for program filings by the major IOUs in 2001.[3] We use a normalized measure life of 20 years in order to capture the benefit of long-lived 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 gas savings by per-unit avoided costs.

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 savings for Measure 3 because its TRC is less than 1.0. The supply curve methodology, when combined with estimates of the TRC for individual measures, produces estimates of the economic potential of efficiency improvements. 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 commercial rates. These scenarios and their associated avoided-cost and rate forecasts are described in Section 5 of this report.

Table 4-6
Sample Use of Supply Curve Framework to Estimate Economic Potential
(*Note: Data are illustrative only*)

Measure	Total End Use Consumption of Population (Mth)	Applicable, Not Complete and Feasible Sq.Feet (000s)	Average thm/ft^2 of population	Savings %	Mth Savings	Total Resource Cost Test	Savings Included in Economic Potential?
Base Water Heating	22.9	300,000	0.076	N/A	N/A	N/A	N/A
1. Tank Insulation	22.9	230,000	0.076	5%	0.9	9.6	Yes
2. Recirc. Pump Clock	22.0	200,000	0.073	3%	0.4	2.9	Yes
3. Active Solar System	21.6	60,000	0.072	60%	2.6	0.6	No
Technical Potential w. all measures				27%	3.9		
Economic Potential w. measures for which TRC > 1.0				6%	1.3		

[3] 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 program and naturally occurring potential.

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 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 a 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.

According to our definitions and the method described in this section, maximum achievable potential is really a type of program potential that defines the upper limit of savings from market interventions. Therefore, in the remainder of this section, we will often discuss our general method using the term program potential to represent both program and maximum achievable potential. The assumptions and data inputs used for the specific program scenarios and maximum achievable potential 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.

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 floor space available for the measure from the technical potential analysis described in Section 4.4, i.e., the total floor space multiplied by the Applicability, Not Complete, and Feasibility factors described previously. We call this the eligible stock. The stock algorithm keeps track of the amount of floor space 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.[4]

Retrofit measures are available for implementation by the entire eligible stock. The eligible stock is reduced over time as a function of adoptions[5] and building decay.[6] Replace-on-burnout measures are available only on an annual basis, approximated as equal to the inverse of the service life.[7] 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.

New construction applications are available for implementation in the first year. Those customers that do not accept the measure are given subsequent opportunities corresponding to whether the measure is a replacement or retrofit-type measure.

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

[4] 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 boiler measure is usually only considered at the end of the life of an existing boiler. By contrast, retrofit measures are defined to be constantly available. For example, application of insulation to an existing water heater tank.

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

[6] Buildings do not last forever. An input to the model is the rate of decay of the existing floor space. Floor space typically decays at a very slow rate.

[7] 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 X will not be available to adopt the efficient alternative again until year X + 15.

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.

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 in order 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 gas savings by retail natural gas rates.[8]

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:

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

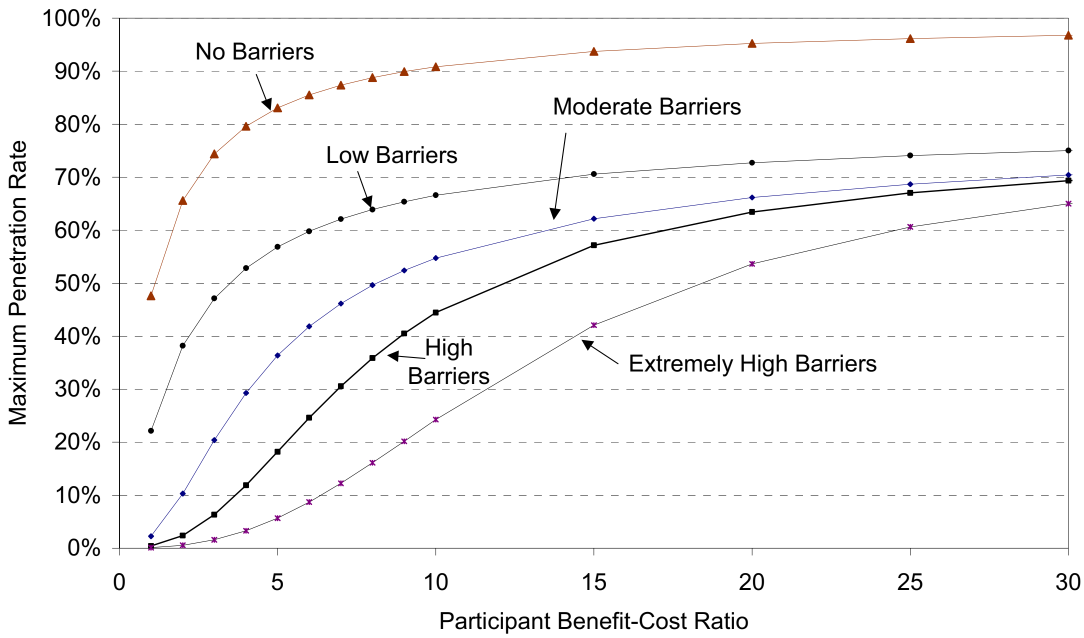
where:

- 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 commercial efficiency programs over the past several years.

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

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

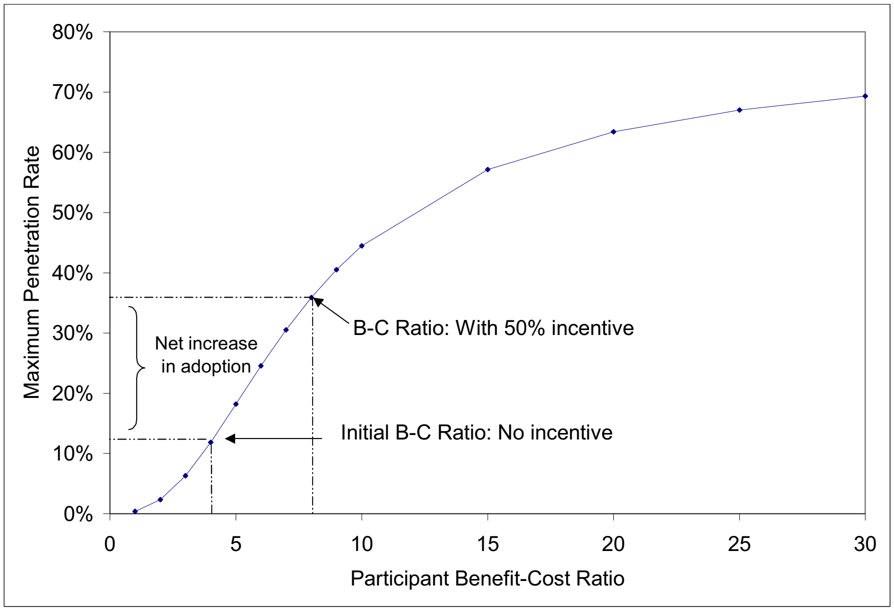


Note that for the moderate, high barrier, and extremely high barrier curves, the participant benefit-cost ratios have to be very high before significant adoption occurs. This is because the participant benefit-cost ratios are based on a 15-percent discount rate. This discount rate reflects likely adoption if there were no market barriers or market failures. Experience has shown, however, that actual adoption behavior correlates with implicit discount rates several times those that would be expected in a perfect market.[9]

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.

[9] 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 well over 100 percent.

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



Scenarios

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 annual streams of achievable program impacts (therms saved) and all societal and participant costs (program costs plus end-user costs). Model results and outputs are shown in Section 7 and Appendix F.

5 DEVELOPMENT OF SCENARIOS

5.1 INTRODUCTION

In this chapter we describe scenarios for which we estimate energy-efficiency potential. 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.

In this study, 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, 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 that 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, there is 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. In addition, the number of scenarios and amount of uncertainty analysis that can or should be conducted is partly limited by the resources

[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.

available for this study. 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 natural gas 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 develop three energy cost elements (Base, Low, and High) and four program funding level elements. These elements are then combined into 12 achievable potential scenarios.

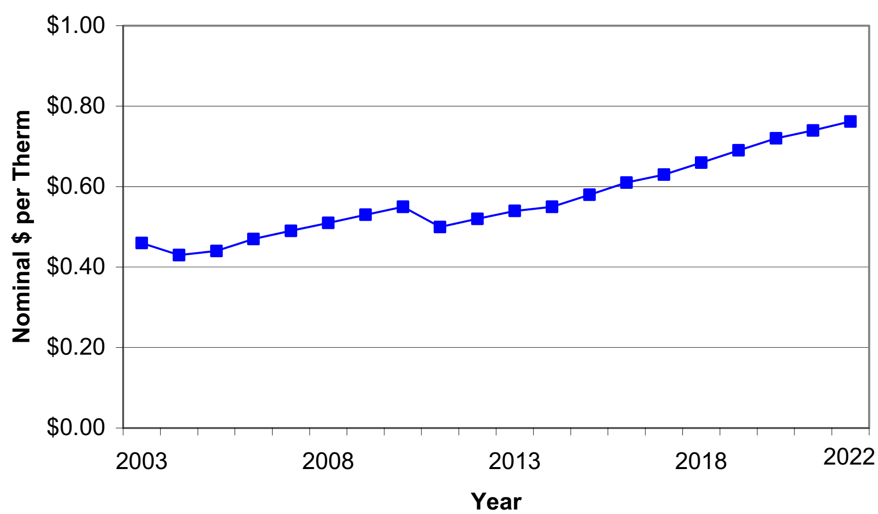
5.2.1 Energy Cost Elements

This study was conducted throughout 2001, a period that coincided with the recent California energy crisis. The advent of the energy crisis created considerable uncertainty in industry estimates of wholesale natural gas prices and rates for the three IOUs delivering natural gas in California. As a result, we created three future energy cost scenario elements: Base, Low, and High.

Base Energy Cost Element

Avoided natural gas costs are shown in Figure 5-3, which are expected to continue to rise over the next 20 years. The base avoided-cost values also are provided in Appendix B. The base natural gas avoided-cost values average $0.57 per therm (nominally) over the next 20 years, which are higher than gas costs seen in the 1990s but lower than those experienced during the recent energy crisis.

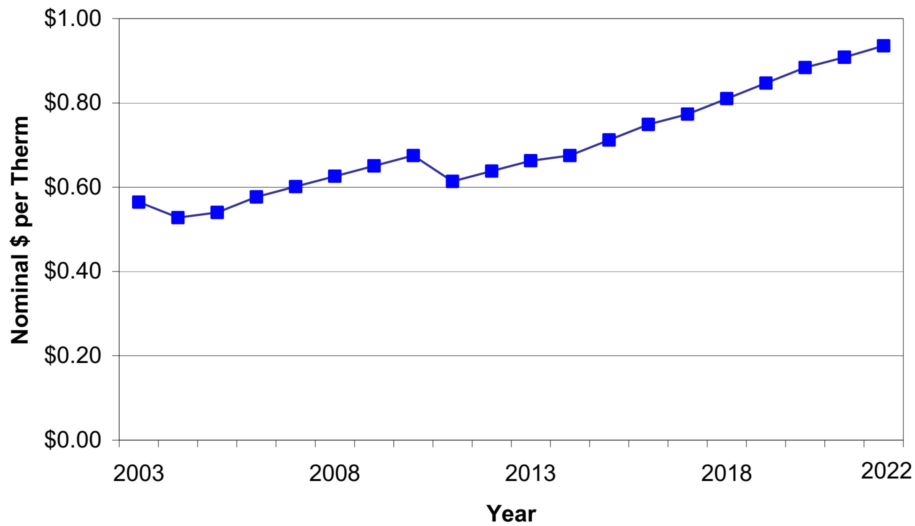
Figure 5-1
Base Avoided Natural Gas Costs



[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.

The base natural gas rate forecast is shown in Figure 5-5. We benchmarked this forecast to average commercial 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.

Figure 5-2
Base Run Commercial Rate Forecast



The base energy cost element is summarized in Table 5-1.

Table 5-1
Summary of Base Energy Cost Element

Cost Type	Description	Source
Avoided Costs	Annual avoided cost averages 46 cents per therm in 2003 and remains relatively unchanged in real terms throughout the forecast horizon.	CPUC authorized avoided costs for 2002 program cost-effectiveness analyses (CPUC 2001).
Commercial Rates	Annual average rate of 56 cents per therm in 2003 that remains relatively flat, in real terms, throughout the forecast horizon.	EIA average commercial 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

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.

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 Low avoided energy costs are simply half of the Base scenario avoided costs throughout the forecast period. The High avoided costs were set at 50 percent above the Base avoided costs throughout the forecast period. Avoided costs scenarios are illustrated in Figure 5-3. Similar to avoided costs, the Low commercial rates were set at half of the base rates, and High commercial rates were set at 50 percent above base rates. A summary of the avoided-cost and rate elements is provided in Table 5-2.

Figure 5-3
Natural Gas Avoided Costs by Energy Cost Scenario

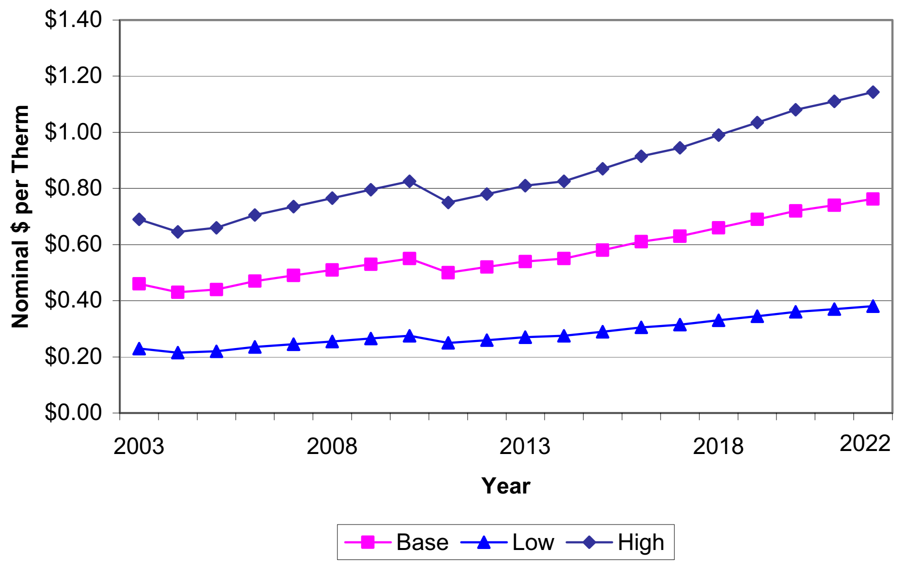


Table 5-2
Summary of Low and High Energy Cost Elements

	Energy Costs Element	
Cost Type	**Low**	**High**
Avoided Costs	50 percent lower than Base avoided costs.	50 percent higher than Base avoided costs.
Commercial Rates	50 percent lower than Base avoided costs.	50 percent higher than Base avoided costs.

5.2.2 Program Funding Elements

In this study, we constructed four different future funding level elements for the major IOUs' natural gas energy-efficiency programs for the commercial existing construction market. These scenarios were initially designed for the companion Commercial Energy Efficiency Potential Study, and this design was extended to this gas study. 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 a "50% Increase" above Level 1, Level 3 represents roughly a "100% Increase" over Level 1, and Level 4 represents the "Maximum Achievable" potential, which equates to a 600 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.

Components

The components of program funding that vary under each of the program funding levels 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.

Level 1 Funding, "Continued Current"

For the Base energy cost scenario, our Level 1 funding was constructed to generally reflect the level of expenditures for the major IOUs' commercial gas-related programs at different points in time over the past 5 years. To develop our Base Level 1 expenditure estimates, we reviewed actual expenditures reported in utility California Public Utility Commission filings and information summarized by the California Energy Commission (CEC). Information on these expenditures is provided in Section 3.2. Also, as discussed in Section 3, there were inconsistencies between the utility data and the CEC data, as well as inconsistencies in how the utilities reported data over the years. After a review of all the various data sources, we determined that approximately $9 million per year was being spent on commercial programs with first-year savings in the neighborhood of 4 Mth.

We reviewed the same sources identified above to estimate program administration and marketing costs. While precise estimates of these costs were not feasible, we estimated that program expenditures made up roughly 80 percent of the total program costs, with financial incentives making up the rest. A large part of the non-incentive program expenditures went to marketing and information programs. As shown in Table 5-3, for our Level 1 funding, we set the initial-year program marketing expenditures at $5 million and administration[3] expenditures at $2 million.

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 5-3. The percent of incremental costs paid by measure is shown in Appendix F. We attempted to set these percentages as closely as possible to the utility incentive levels in recent years. Aligning our percentages with the actual per-unit amounts paid for by the programs is difficult for several reasons. First, incentives in the nonresidential SPC program are set as a function of savings by end use (i.e., dollars per therm saved). Second, even where prescriptive incentives exist, namely the Express Efficiency program, the amount paid has varied somewhat over the past few years because of extras provided to stimulate participation, especially among smaller customers (e.g., summer and vendor bonuses). Notwithstanding the caveats above, we believe that the percent of measure costs paid in our Level 1 funding element, which average about one-third of measure costs, reasonably approximates actual program incentive levels over the past few years.

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.[4] The percent of incremental measure costs paid over time is held constant.

Level 2 and Level 3 Funding, "50 Percent and 100 Percent Increase"

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.

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

[4] 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 ($therms_x$) and first-year program savings ($therms_1$) as follows: $AC_t = 0.75 \times therms_t/therms_1$, 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.

Administration levels increase as noted above as a function of increases in program activity. As noted 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 below in Table 5-3, marketing costs average just under $6 million per year for Level 2 and just over $6 million per year for Level 3. The average fraction of incremental costs paid for by incentives increases from roughly one-third in Level 1 to approximately half in Level 2 and two-thirds 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.

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 5-3 shows the combinations.

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

1. Only measures that are cost-effective based upon the economic potential analysis, as defined in Section 4.5, enter into the achievable potential analyses
2. Adoption levels for individual measures will vary across energy cost elements because of differences in commercial rates.

Whether a measure is cost-effective based upon the economic potential analysis depends on whether its 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 commercial 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.

5.2.4 Summary of Program Expenditures by Scenario

With the background discussion above, we can now summarize the actual funding levels that are both input and estimated for each scenario. These values are shown in Table 5-4 and discussed further in the program potential results section of this report (Section 7). Year-by-year funding levels are shown in Appendix F.

Table 5-3
Summary of 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)	$5	$2	$2	$9	33%
Base – "50% Increase" (L2)	$6	$3	$5	$14	60%
Base – "100% Increase" (L3)	$6	$7	$10	$23	75%
Base – "Max Achievable" (L4)	$6	$12	$47	$65	100%
Low – L1	$5	$2	$0.2	$7	33%
Low – L2	$6	$2	$1	$9	60%
Low – L3	$6	$8	$1	$15	75%
Low – L4	$6	$12	$8	$26	100%
High – L1	$5	$1	$2	$8	33%
High – L2	$6	$2	$5	$12	60%
High – L3	$6	$4	$9	$19	75%
High – L4	$6	$9	$74	$89	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 33 percent of measure costs paid under Level 1 funding.

5.3 ACHIEVABLE POTENTIAL SCENARIO CALIBRATION

Since consistent estimates program expenditures and accomplishments for commercial gas programs are not available, we calibrated the aggregated numbers to the extent possible with the existing data. For our base funding level, our model predicts first-year natural gas savings of approximately 3.8 Mth with first-year program expenditures of $8.5 million. We believe this calibration effort puts our model in the ballpark, but we note considerable uncertainty in our findings.

6 TECHNICAL AND ECONOMIC POTENTIAL RESULTS

This section provides our estimates of technical and economic energy-efficiency potential for natural gas for the existing construction portion of the commercial sector of the major IOU's service territories. We find that there are significant, still-available, untapped natural gas savings potential. Technical energy savings potential is estimated to be approximately 750 Mth, and economic potential is estimated to be 430 Mth (or between 21 and 35 percent of expected commercial gas consumption). There is, however, considerable uncertainty around these results.

The methodologies used to develop these estimates are described in Section 4. The energy cost scenarios for which estimates are presented are described in Section 5. Section 7 discusses the actual program potential associated with these results.

6.1 INTRODUCTION

A total of 26 commercial natural gas measures were used in the analyses. The complete set of measures considered was pre-screened to only include those measures that are presently commercially available. Thus, emerging technologies were not included in the analysis. The measure analysis was segmented into 10 commercial building types for each of the 3 gas IOU service territories. For weather-sensitive measures, we further segment by the 14 California Energy Commission (CEC) forecasting climate zones covering the major gas IOUs. As a result, our analyses were conducted for roughly 700 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 commercial natural gas consumption; and 2) percent of energy addressed*,* as discussed in more detail below. We base our analysis on the CEC's end-use forecast data for 2000.[1] Total base energy is the CEC's estimate of the amount of natural gas consumed for all end uses and building types in the commercial sector for the IOUs in 2000.

For commercial natural gas consumption, the total base gas use estimated for 2000 in the major IOUs is roughly 2,116 Mth.

Energy-efficiency measures are analyzed for the most important end uses. In particular, we have not included measures to address the miscellaneous end use, with the exception of commercial natural gas pool heating, which makes up a significant portion of the miscellaneous end use (approximately 20 percent). The miscellaneous end-use category also includes clothes drying,

[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.

fireplaces, and gas cooling, and only represents about 9 percent of total commercial natural gas use. As a result, the end uses for which we do apply efficiency measures account for approximately 93 percent of total commercial natural gas use, or about 2,000 Mth. We refer to the energy-efficiency estimates based on the major end uses as the base natural gas use addressed.

6.2 NATURAL GAS TECHNICAL AND ECONOMIC POTENTIAL UNDER BASE ENERGY COSTS

This section presents technical and economic potential estimates under the base natural gas costs described in Section 5. Economic potential under the alternative Low and High natural gas costs is presented in Section 6.3.

6.2.1 Aggregate Gas Technical and Economic Savings Potential by Utility

Figure 6-1 presents estimates of total technical and economic potential for natural gas. In Figure 6-2 we show technical and economic potential by utility. Overall, technical natural gas savings potential is estimated to be 750 Mth, about 35 percent of total commercial gas usage (i.e., 750 Mth Savings/2,116 Mth of base consumption) and 38 percent of the base energy addressed (i.e., 750/1,964). Economic potential is estimated to be approximately 430 Mth, about 21 percent of both total base usage and base energy addressed. Pacific Gas & Electric (PG&E) is estimated to have the largest share of economic energy savings potential at about 10 percent of the total consumption, followed closely by Southern California Gas (SCG) at 8 percent and then San Diego Gas & Electric (SDG&E) at 2 percent. Differences are due to a number of factors such as climate, end-use saturations, and the current penetration of energy-efficiency technologies.

Figure 6-1
Estimated Technical and Economic Potential for Natural Gas
(Commercial Sector Existing Construction, PG&E/SCG/SDG&E)

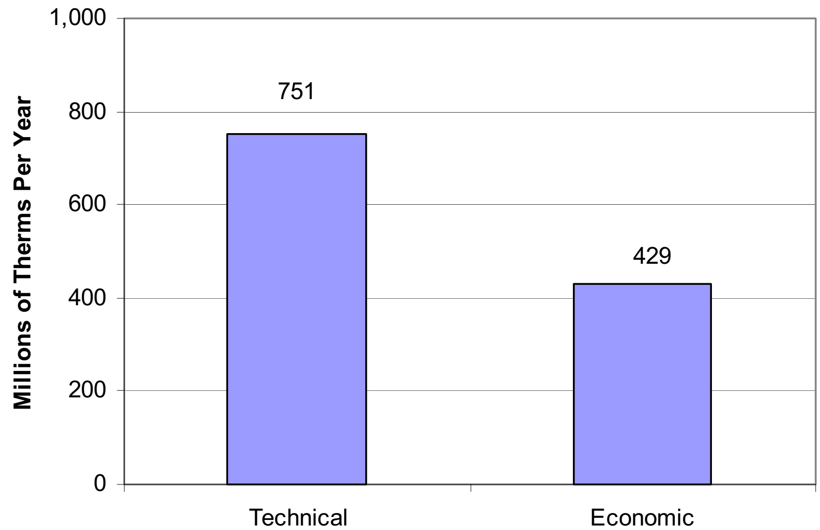
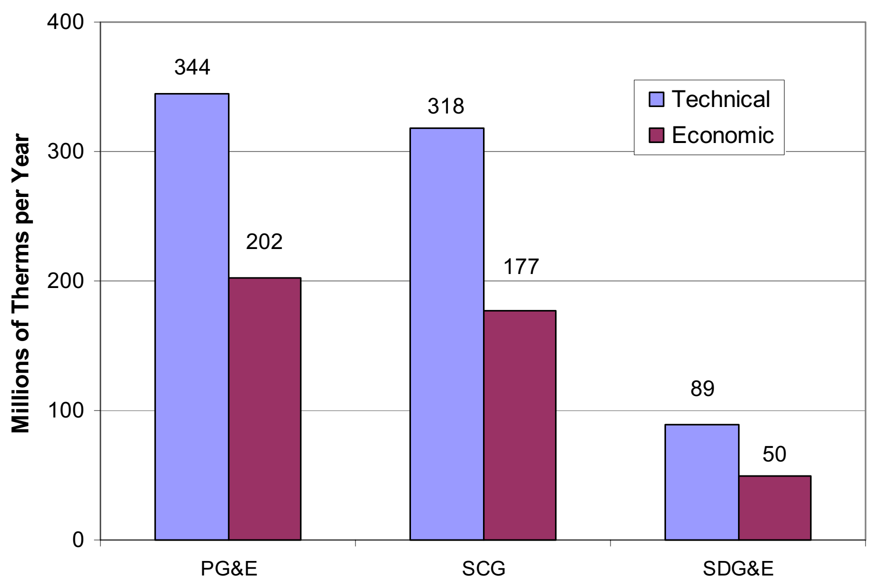


Figure 6-2
Commercial Gas Energy Savings Potential by Utility



6.2.2 Technical and Economic Savings Potential by End Use and Measure

Estimates of natural gas savings potential are provided by end use in Figures 6-3 and 6-4. The first of the figures provides savings in absolute terms; the second, in terms of the percentage of base-case end-use energy. Commercial water heating represents the largest end-use savings potential in absolute terms, at 18 percent of total commercial natural gas consumption. Heating and cooking end uses also represent significant end-use savings potential as well, at 11 percent and 7 percent of total gas consumption, respectively. Water heating also represents the greatest potential when examined by percent of end use consumption. Economic savings potential values are summarized by end use and utility in Table 6-1.

Figure 6-3
Commercial Gas Energy Savings Potential by End Use

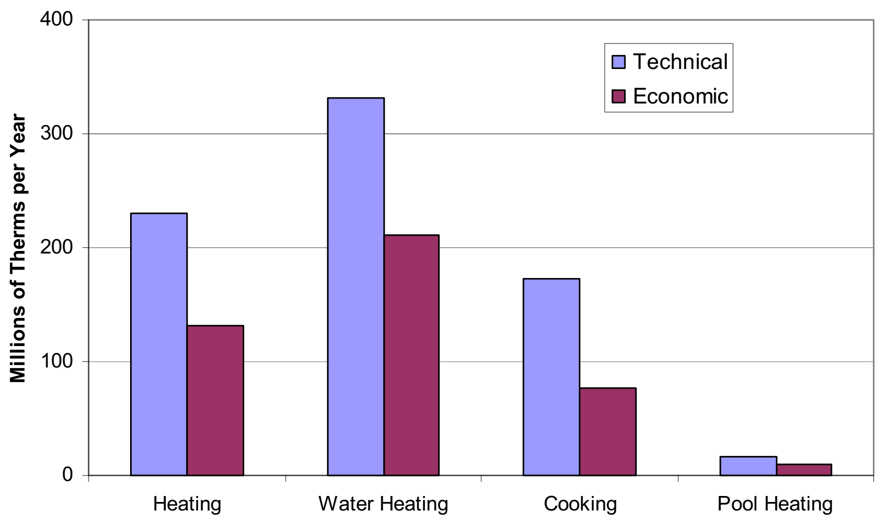


Figure 6-4
Commercial Gas Energy Savings Potential as Percent of Base End-Use Consumption

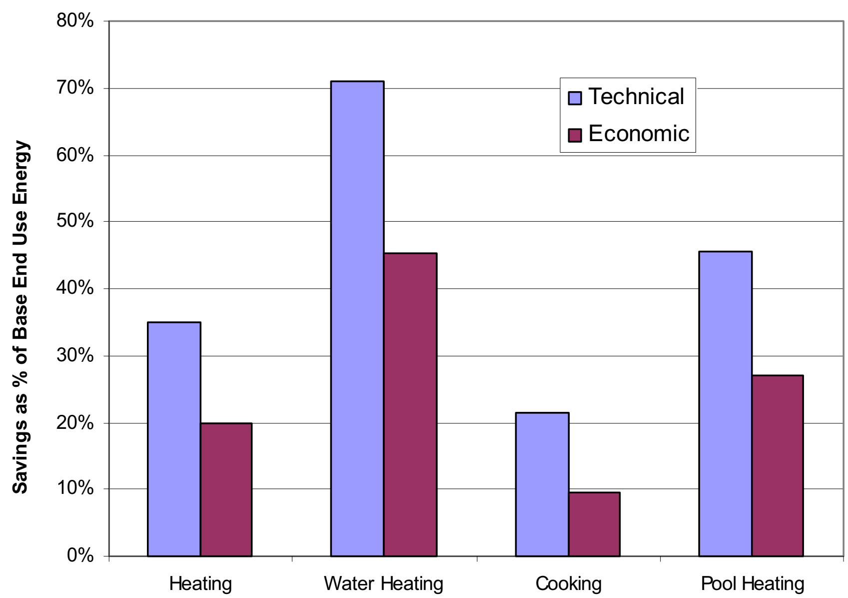


Table 6-1
Commercial Gas Economic Savings Potential by End Use and Utility (in Mth)

	PG&E	SCG	SDG&E	TOTAL
Heating	86	35	9	131
Water Heating	92	92	27	211
Cooking	19	46	12	77
Pool Heating	5	3	1	10
Total	202	177	50	429

In Figure 6-5, we present estimates of technical potential by measure in terms of energy. In terms of natural gas savings, the solar domestic hot water (DHW) system is the measure with the largest technical potential, representing roughly 25 percent of estimated commercial gas technical potential. High-efficiency (HE) furnace/boilers and gas water heaters offer the second and third most technical potential at 14 percent and 13 percent, respectively. Infrared fryers, double-pane windows with low-emissivity (low-E), and infrared conveyer ovens round out the measures that represent roughly 5 percent or more of total energy savings potential. The remaining measures represent about 28 percent of energy potential.

Figure 6-5
Commercial Gas Technical Savings Potential by Measure

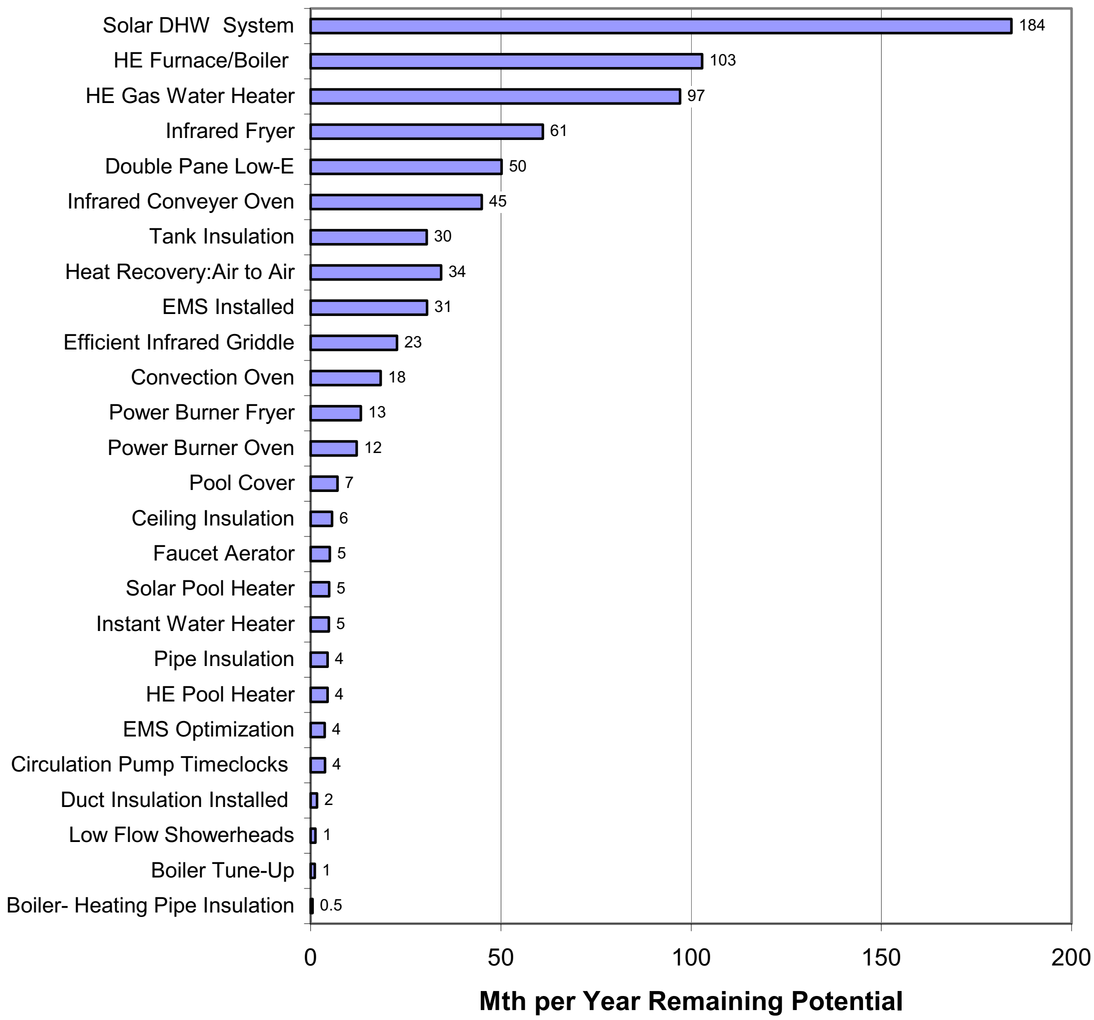


Table 6-2 summarizes issues and observations associated with the development of these results.

Table 6-2
Key Data Limitations Associated with Estimates of Commercial Gas Potential

End Use	Key Uncertainties
All	***End-use intensity (referred as "EUI", typically for gas, therms or kBtu/square foot-year), fuel saturation, and unit intensity (e.g., kBtu of furnace capacity/square foot) estimates***. There is considerable divergence in estimates of base-case end-use consumption among the key sources that we utilized for this study (CEC 2000, PG&E 1999, SDG&E 1999, and SCG 1992). In particular, the CEC EUI and saturation estimates differ markedly from those in the recent (late-1990s) CEUS projects for PG&E and SDG&E. Because the CEC end-use consumption estimates included what we considered to be unreasonably high consumption estimates for the miscellaneous end use, we used the more recent PG&E and SDG&E CEUS studies as the basis for gas fuel shares and EUIs. However, these sources also vary in counter-intuitive ways with respect to EUIs by building type. In addition, most existing sources lack adequate internal consistency between estimates of end-use intensity and equipment unit intensity. In this potential study, unit intensity (e.g., kBtu of capacity/ft^2, linear feet of pipe/ft^2, etc.) estimates are needed to convert measure costs to costs per square foot so that costs and savings are expressed in the same terms. An updated and internally consistent source of estimates of baseline EUI, saturation, and unit intensity data is needed. The CEC is currently managing a comprehensive, statewide CEUS that, when completed, should provide these data. ***Existing measure saturation estimates***. Reliable estimates of the current saturation of energy-efficiency measures in existing commercial buildings are outdated. Currently, the principal data sources for measure saturation estimates are commercial end-use surveys (CEUS) conducted by the IOUs in the mid-1990s. The new CEUS being managed by the CEC should provide updated measure saturation estimates.
Space Heating	***Energy savings.*** Energy savings estimates were obtained from a combination of sources, including the commercial gas savings portion of the DEER database (NEOS 1994), engineering estimates, and a previous gas potential study (SCG 1992). The DEER estimates are based on DOE-2 building simulations. These savings estimates, though useful, are available for only 14 building types. Savings for weather-sensitive measures vary widely across these prototypes as a function of assumed building envelope and internal gain characteristics. This sometimes results in significant aggregation bias in which savings may be very large for some building types and virtually zero for others. Significant new primary research is needed to refine savings estimates for natural gas heating measures. ***Cost prorating***. A number of gas measures provide savings for both space heating and electric cooling (e.g., energy management systems, low-e windows, and duct insulation and repair). For these measures, incremental costs were prorated so that only a portion of the costs was applied to our estimates of the cost-effectiveness of the gas measure. For these duel-fuel measures, only one-third of the incremental measure cost was applied to the gas savings. Obviously the ratio of costs and savings between fuels for measures that apply to both gas heating and electric cooling can range considerably. Further research is needed to better assess the allocation of costs for measures that affect both gas heating and electric cooling.

End Use	Key Uncertainties
Domestic Hot Water	***Energy savings.*** Energy savings estimates were based primarily on engineering estimates, SCG's 2002 program application, and a previous gas potential study (SCG 1992). Savings estimates were generally based on professional judgment and reflect rough averages of savings across all building types. Further primary research is needed to refine these estimates, especially by building type. In particular, well-documented DHW consumption prototypes should be developed that clearly match incremental cost, savings, and unit intensity (e.g., number of linear feet of pipe/square foot, number of faucets/square foot, etc.) assumptions. Note that this work may be conducted as part of the update to DEER planned for 2003.
Cooking	***Costs and savings***. The efficiency of cooking equipment is not easily measured, and there is no standardized efficiency rating system for cooking equipment. In-situ cooking consumption varies widely as a function of many factors, including the type and amount of food cooked. Because efficiency is not always apparent, it is difficult to identify and isolate incremental costs associated with higher efficiency units. Several industry laboratories, including the Fisher-Nickel Food Service Technology Center, seek to address this information barrier by testing individual pieces of cooking equipment under controlled conditions. Often, these test results are then disseminated to cooking end users and manufacturers. It is difficult, however, to compile this information into estimates of average costs and savings that can be applied to the entire population of cooking facilities in the state. Further work is needed to try to periodically compile the results of laboratory and field tests into useful averages that can serve as the basis for cost-effectiveness testing for measures that benefit from public goods-based funds.
Pool Heating	***Base consumption and measure saturation***. Few existing sources disaggregate pool consumption from the major gas end uses. Total base consumption for the population is estimated in this study by weighting up a prototypical pool's consumption based on the saturation of pools obtained from the PG&E and SDG&E CEUS studies. In addition, the fraction of pools for which pool covers are actively utilized is currently uncertain.

6.2.3 Energy-Efficiency Supply Curves

Our commercial sector energy-efficiency supply curves are shown in Figures 6-6 for natural gas savings potential. The curves are shown in terms of savings as a percentage of total commercial sector natural gas consumption addressed. Note that our economic potential figures are based on the TRC test, as described in Section 4. Also note that our avoided-cost benefit values include only natural gas savings benefits. Thus, our economic potential integrates the value of the savings potentials shown in the energy-efficiency supply curve figures.

In Table 6-3 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 E, though the results in this appendix are not additive.

Figure 6-6
Commercial Gas Energy-Efficiency Supply Curve

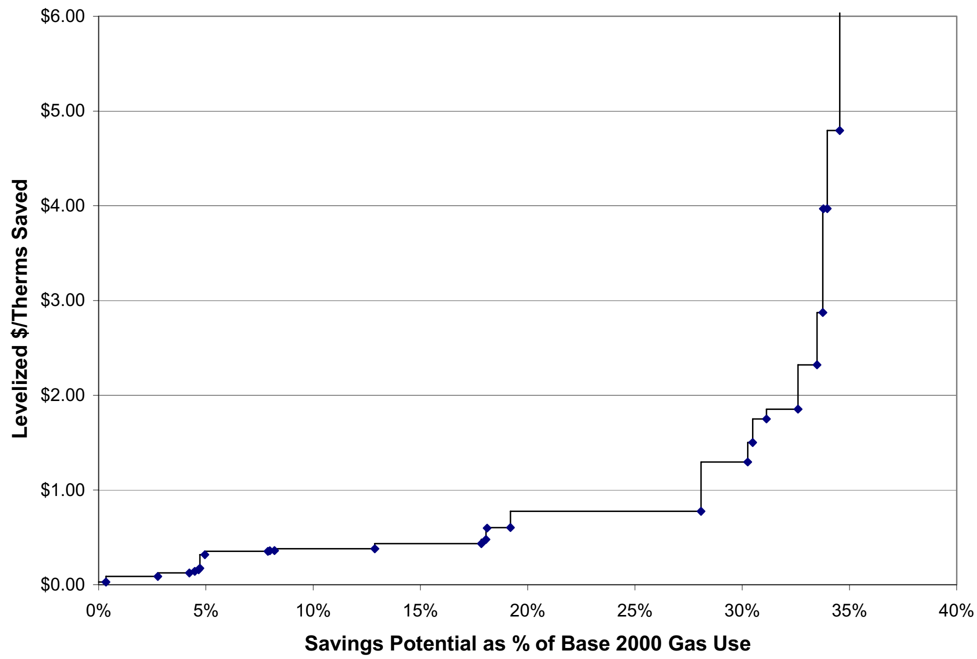


Table 6-3
Aggregated Measure Values for Energy-Efficiency Supply Curves for Commercial Gas

Measures	Mth Savings	Cumulative Mth Savings	Levelized Energy Cost $/Therm	Cumulative Percent Savings
Pool Cover	7	7	$ 0.03	0%
Double Pane Low-E	50	57	$ 0.09	3%
Tank Insulation	30	88	$ 0.12	4%
Faucet Aerator	5	93	$ 0.14	4%
Circulation Pump Time Clocks	4	97	$ 0.16	5%
Low Flow Showerheads	1	98	$ 0.17	5%
Instant Water Heater	5	103	$ 0.32	5%
Infrared Fryer	61	164	$ 0.35	8%
Duct Insulation Installed	2	165	$ 0.36	8%
Pipe Insulation	4	170	$ 0.36	8%
HE Gas Water Heater	97	267	$ 0.38	13%
HE Furnace/Boiler	103	370	$ 0.43	17%
HE Pool Heater	4	374	$ 0.48	18%
Boiler Tune-Up	1	375	$ 0.60	18%
Efficient Infrared Griddle	23	398	$ 0.60	19%
Solar DHW System	184	582	$ 0.77	28%
Infrared Conveyer Oven	45	627	$ 1.29	30%
Solar Pool Heater	5	632	$ 1.50	30%
Power Burner Fryer	13	645	$ 1.75	31%
EMS Installed	31	676	$ 1.85	32%
Convection Oven	18	694	$ 2.32	33%
Ceiling Insulation	6	700	$ 2.87	33%
Boiler- Heating Pipe Insulation	0	701	$ 3.97	33%
EMS Optimization	4	704	$ 3.97	33%
Power Burner Oven	12	716	$ 4.79	34%
Heat Recovery: Air to Air	34	751	$ 9.80	35%

6.3 NATURAL GAS ECONOMIC POTENTIAL UNDER LOW AND HIGH ENERGY COSTS

This subsection presents 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 6-7 and 6-8 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 approximately 50 percent for energy savings as compared to the Base scenario. Economic potential under the High energy costs scenario is 23 percent above that of the Base scenario. The spread of economic potential under uncertain avoided costs is quite large, ranging from roughly 210 Mth to 530 Mth. Results by end use are compared in Figure 6-9.

Figure 6-7
Commercial Gas Economic Potential By Energy Cost Scenario

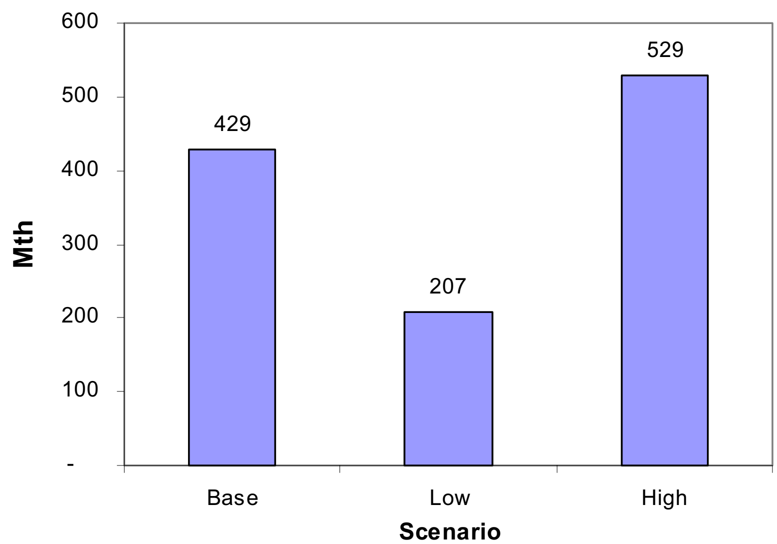


Figure 6-8
Commercial Gas Economic Potential as Percent of Base Consumption By Energy Cost Scenario

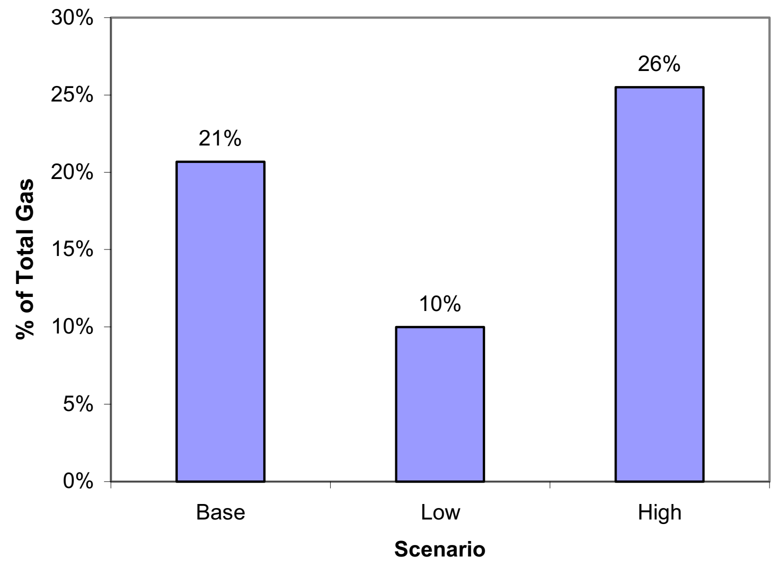
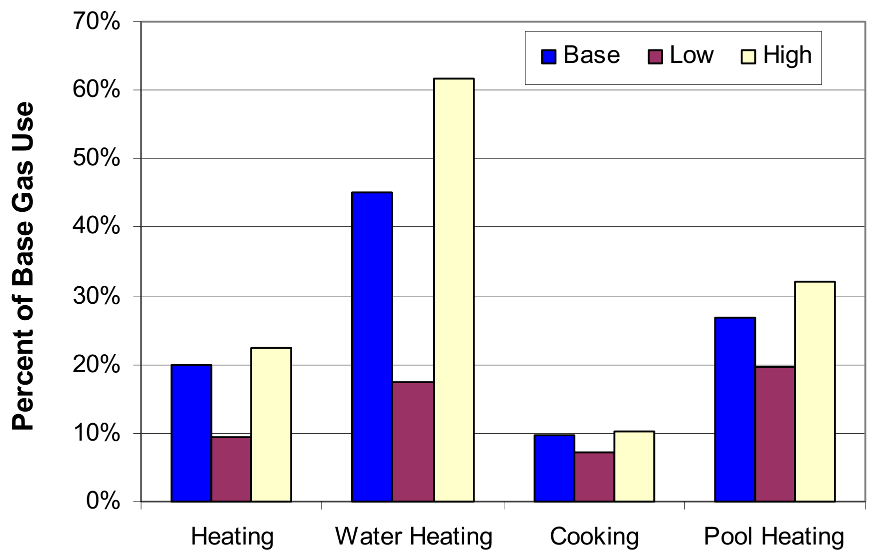


Figure 6-9
Commercial Gas Economic Potential as Percent of Base End-Use Consumption by Energy Cost Scenario



From these estimates of economic potential, we proceed to estimate achievable program potentials for natural gas savings in the commercial sector as presented in Section 7.

7 PROGRAM POTENTIAL RESULTS

This section presents the results of our natural gas achievable program potential estimates for the existing construction portion of commercial buildings in the service territories of the major investor-owned utilities. To deal with the increased uncertainty of modeling inputs, program potential is estimated under several scenarios that reflect a range of possible alternative futures.

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

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

7.1 REVIEW OF SCENARIOS UNDER WHICH ACHIEVABLE PROGRAM POTENTIALS ARE ESTIMATED

In Section 5, we discussed that there is 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 are those associated with future wholesale and retail energy 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 7-1 and discussed further in Section 5.

Table 7-1
Summary of Energy 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 46 cents per therm in 2003.	50 percent higher than Base avoided costs.
Commercial Rates	50 percent lower than Base rates.	Annual average rate of 56 cents per therm in 2003 that remains relatively flat, in real terms, throughout the forecast horizon.	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 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.

7.2 Naturally Occurring Efficiency Results

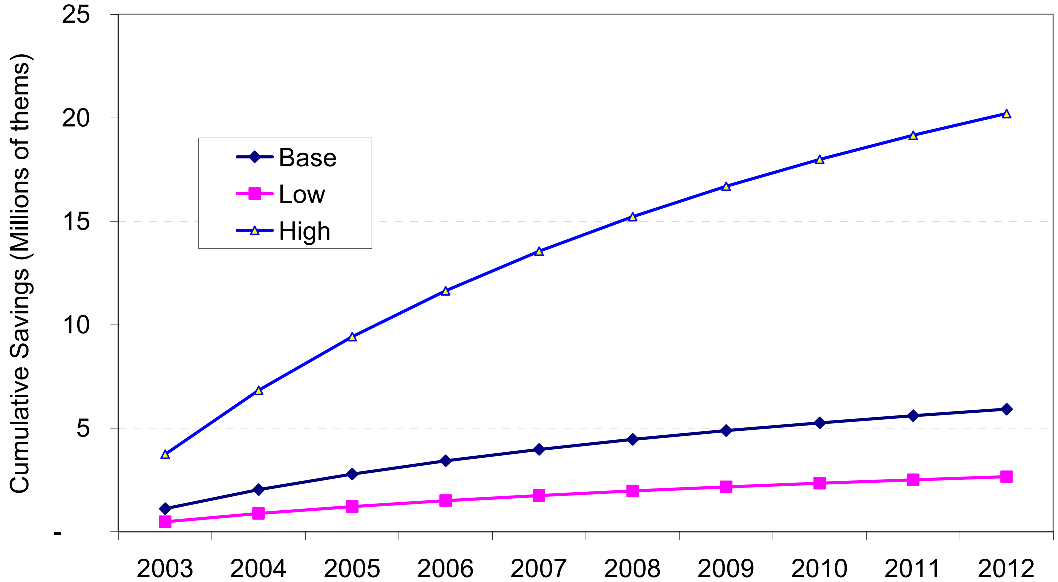
Before presenting the net program potential results, we first present our estimates of naturally occurring efficiency savings under our three economic scenario elements. This is because total or gross program potential includes naturally occurring savings. Net program savings exclude naturally occurring 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 energy price elasticity.[1]

Before examining the naturally occurring estimates, readers may want to review our discussion of how customer adoption of efficiency measures is modeled in Section 4. In 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 2012. 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, which declined fairly sharply since the energy crisis, remain fairly constant (in real terms) over the next 10 years. Under the High scenario, the customer decision is modeled as if the customer “believes” that rates remain at roughly energy crisis levels indefinitely.

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

Naturally occurring natural gas savings are shown for the three economic scenario elements in Figure 7-1.

Figure 7-1
Naturally Occurring Natural Gas Efficiency Energy Savings by Economic Scenario



Annual naturally occurring natural gas 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. Naturally occurring gas savings under the Base economic cost assumptions start off at roughly 1 Mth per year and average only 0.6 Mth annually over the 10-year period.

In the Low scenario naturally occurring savings are about half of the savings found in the Base scenario. In the case of the High scenario, naturally occurring savings increase dramatically, more than tripling the savings estimates.

7.3 PROGRAM POTENTIAL RESULTS BY SCENARIO

In this subsection we present the results from our estimates of commercial gas program potential under the 12 scenarios summarized at the outset of this chapter and defined in Section 5. We forecasted program natural gas savings under each scenario for a 10-year period beginning in 2003. We developed a rough calibration of our energy-efficiency adoption model to recent program accomplishments as discussed at the end of Section 5.

Our estimated energy potentials are shown under each energy cost scenario in Figures 7-2 through 7-4. In Table 7-2 (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.

7.3.1 Program Potential Under Base Energy Costs

As shown in Figure 7-2 and Table 7-2, under the Base energy costs scenarios, net program energy savings potential ranges from roughly 30 Mth under "Continued Current" (Level 1) funding to almost 195 Mth under "Max Achievable" (Level 4) funding.

"Continued Current" funding under Base energy costs is similar to funding levels in 1999 and 2000, with incentives set at an average of 33 percent of measure costs. Under the "Continued Current" funding with Base energy costs scenario, we estimate that about 7 percent of the economic potential of 430 Mth would be captured over the forecast period.

"Max Achievable" funding is 600 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 45 percent of the economic potential could be captured.

Level 2 and Level 3 are scenarios in which expenditures are roughly 50 percent and 100 percent greater than the Level 1 expenditures under the Base energy cost assumptions. Incentives eventually average approximately 50 percent under the "50% Increase" scenario and 66 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 approximately 49 Mth and 75 Mth, respectively.

7.3.2 Program Potential Under High and Low Energy Costs

Estimates of program potential under the Low energy costs scenarios are shown in Figure 7-3. As one would expect, under Low energy costs, net program energy savings potentials are significantly smaller than under Base energy costs, ranging from roughly 10 Mth under Level 1 funding to approximately 86 Mth under Level 4 funding. The Low scenario potentials decrease relative to the Base potentials as funding levels increase, from 33 percent of the Base potential under Level 1 funding to 45 percent of Base under Level 4. Energy savings under Low energy costs for Levels 2 and 3 are approximately 19 and 31 Mth, respectively.

Estimates of program potential under High energy costs are shown in Figure 7-4. Program energy savings potentials under the High scenarios are moderately higher than under Base energy costs, ranging from roughly 29 Mth under Level 1 funding to approximately 206 Mth under Level 4 funding. Energy savings under High energy costs for Levels 2 and 3 are approximately 45 and 65 Mth, respectively.

Program potentials under the High scenario are almost identical for Level 1 funding as under Base energy costs and are only 7 percent higher for Level 4 funding. This is in part because naturally occurring efficiency savings are almost twice as high under the High energy costs scenario as they are under the Base case. Thus, the gross savings (i.e., including naturally occurring) are higher under the High case than under the Base energy costs, as can be seen by comparing Figures 7-2 and 7-4.

Figure 7-2
Program Natural Gas Savings Potential by Program Activity Level - BASE Energy Costs

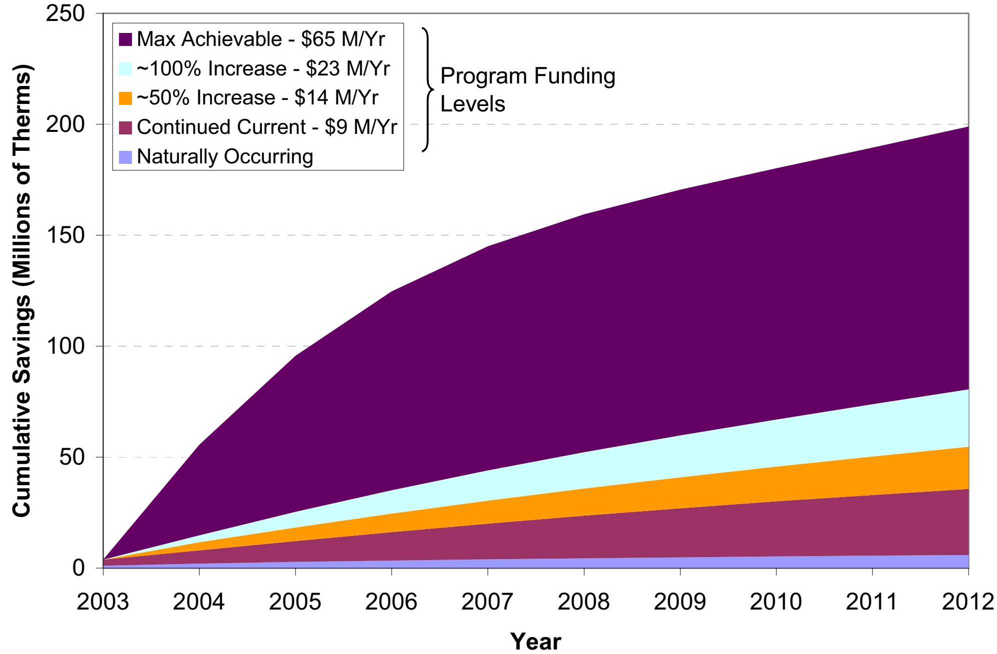


Figure 7-3
Program Natural Gas Savings Potential by Program Activity Level - LOW Energy Costs

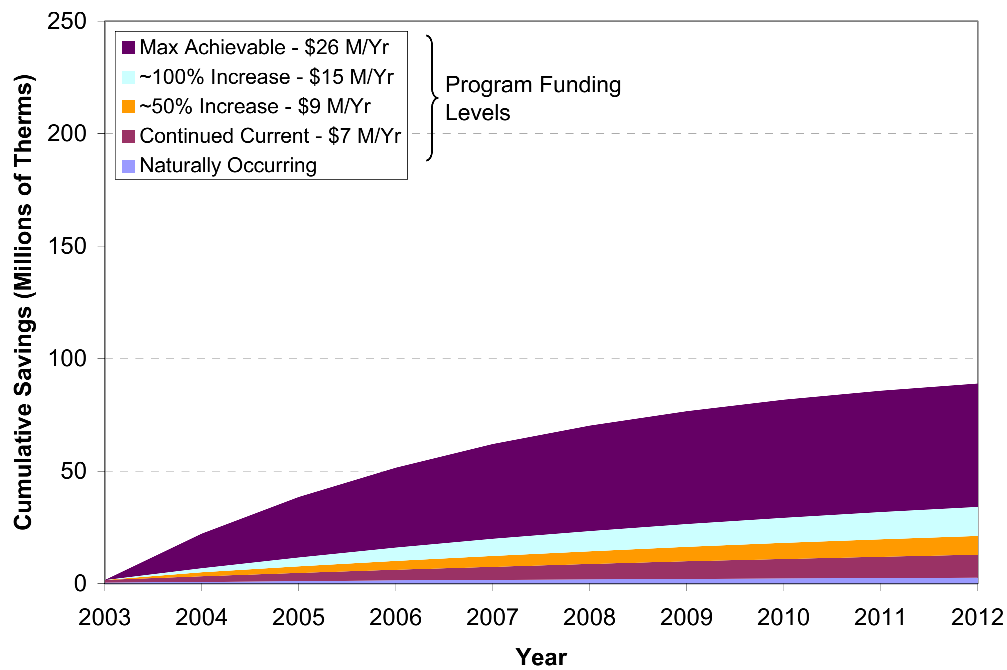
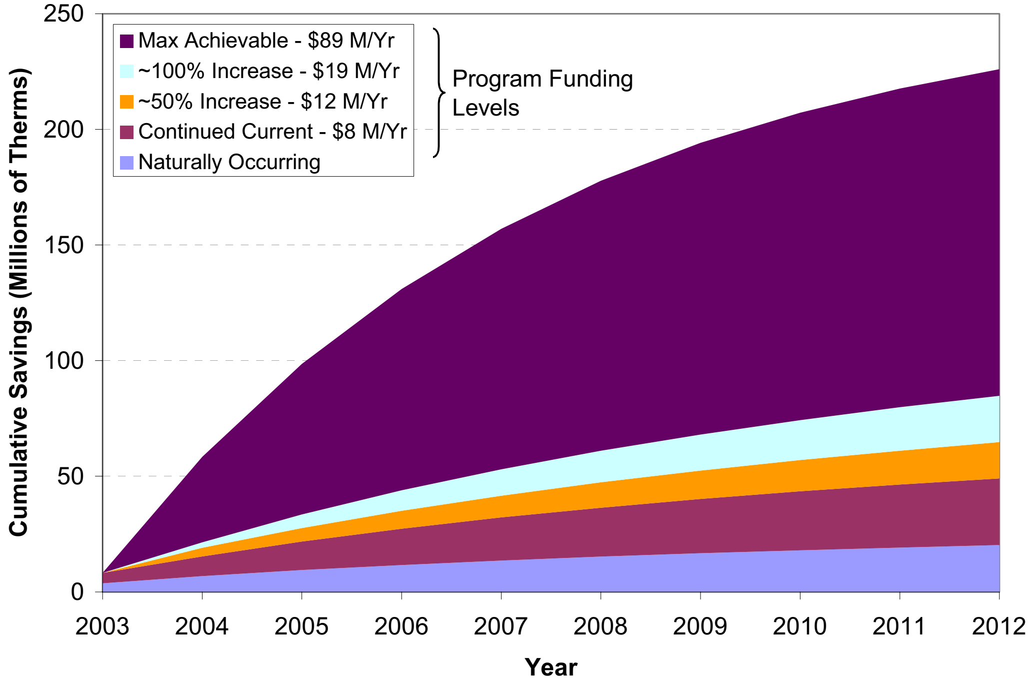


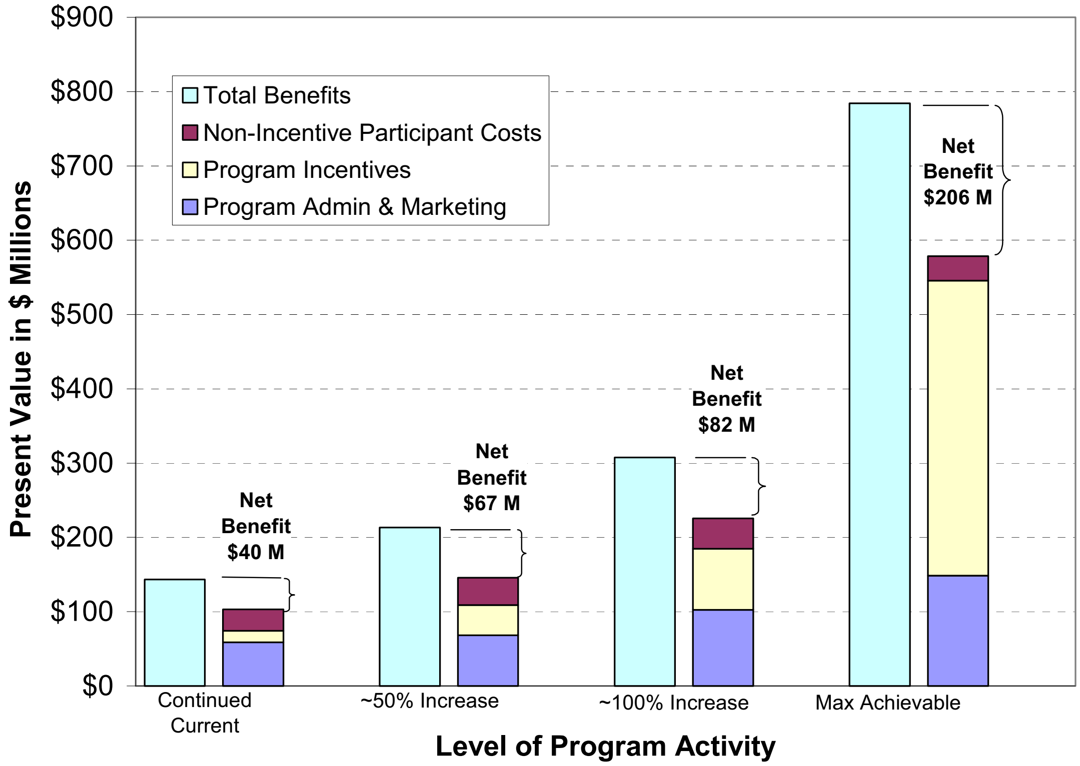
Figure 7-4
Program Natural Gas Savings Potential by Program Activity Level - HIGH Energy Costs



7.3.3 Cost and Benefit Results

The costs and benefits associated with the commercial efficiency funding scenarios under Base energy costs over the 10-year period are shown in Figure 7-5. As shown in the figure, total program costs vary from roughly $100 million under the “Continued Current” scenario, to about $150 million under “50% Increase,” to $225 million under “100% Increase,” to approximately $575 million under “Max Achievable.” Total avoided-cost benefits range from $143 million under “Continued Current” to $784 million under “Max Achievable.” Net avoided-cost benefits, which are the difference between total avoided-cost benefits and TRCs (which include participants’ costs), range from $40 million to about $200 million. All of the funding scenarios for Base and High are cost effective based on the TRC test, which is the principal test used in California to determine program cost effectiveness. However, none of the scenarios under Low are cost effective.

Figure 7-5
Costs and Benefits of Commercial Electric Efficiency Savings – 2002 to 2011
(under Base Energy Costs Scenario)



*Note: Participant costs minus incentives account for the difference between program costs and total resource costs.

TRC test and other results are shown in Table 7-2 for all scenario runs. The results shown indicate that only the Base and High scenarios are cost effective based on the TRC. TRC values range from a high of 3.3 under the High energy costs with Level 1 funding scenarios to a low of 0.44 under the Low energy costs with funding Level 1 scenario. TRC values under the Base energy costs range from 1.36 for Level 3 and 4 funding to 1.46 for Level 2. The results show that TRC values are much more sensitive to energy cost assumptions than they are to funding levels.

The TRC values have a tendency 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 somewhat is 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.

While it is useful to know that most of the program potential forecasts were cost effective under our energy cost scenarios, cost-effectiveness screening does not answer the larger resource-planning question of how much energy efficiency is optimal from a societal or utility perspective. To determine the optimal mix of resources, a broader analytical framework is necessary, as we discuss in Section 9.

Table 7-2
Summary of 10-Year Net Program Potential Results*

Scenario		Level 1	Level 2	Level 3	Level 4
Base	Program Costs:	$74 MM	$109 MM	$185 MM	$545 MM
	Participant Costs:	$29 MM	$37 MM	$41 MM	$33 MM
	Benefits:	$143 MM	$213 MM	$308 MM	$784 MM
	Net Therm Savings (in Millions):	30	49	75	193
	Program TRC:	1.39	1.46	1.36	1.36
Low	Program Costs:	$57 MM	$70 MM	$120 MM	$219 MM
	Participant Costs:	$3 MM	$5 MM	$6 MM	$7 MM
	Benefits:	$26 MM	$42 MM	$65 MM	$173 MM
	Net Therm Savings (in Millions):	10	19	31	86
	Program TRC:	0.44	0.56	0.52	0.76
High	Program Costs:	$68 MM	$98 MM	$151 MM	$746 MM
	Participant Costs:	$31 MM	$37 MM	$40 MM	$52 MM
	Benefits:	$309 MM	$396 MM	$506 MM	$1,333 MM
	Net Therm Savings (in Millions):	29	45	65	206
	Program TRC:	3.13	2.95	2.65	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.

8 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.

8.1 SUMMARY OF CONCLUSIONS

Key conclusions from this study are summarized below:

- For the commercial sector, compared to electricity, the data available addressing end-use energy consumption of natural gas is less developed. Therefore, we calibrated the numbers used in our model to the extent possible to minimize the uncertainties in end-use energy usage estimates. However, the differences in usage estimates developed by the California Energy Commission (CEC) and by the California utilities create uncertainty that limits the accuracy of our potential estimates and cost-effectiveness tests, which are based on detailed analyses at the end-use level.
- Reporting of past energy-efficiency program activity directed at commercial natural gas savings also differs by reporting entity. To the extent feasible, we have benchmarked our market potential analysis to actual program performance. However, program cost and savings estimates developed by the CEC vary significantly from numbers reported by the utilities, and utility disaggregation of nonresidential natural gas programs between the commercial and industrial sectors has changed over time, due in part to changes in reporting requirements.
- There appears to be modest additional remaining achievable and cost-effective potential for natural gas energy-efficiency savings in the commercial sector over the next 10 years. Under our "Business-as-Usual" program-funding scenario, we estimate savings of about 30 Mth over the next 10 years, about 1.5 percent of total commercial natural gas use.
- In addition, our results suggest that there is additional achievable and cost-effective commercial gas savings potential beyond the savings that are likely to occur under a continuation of current public goods funding levels. Capturing this additional achievable program potential would require an increase in activity levels for energy-efficiency programs. For example:
    - Increasing commercial natural gas program activity over the next 10 years by 250 percent could save an additional $165 million on natural gas costs (going from an estimated savings of $143 million under current activity levels to $308 million).
- There is considerable uncertainty in two of the principal forecasting inputs necessary for analyzing the cost effectiveness of electric energy efficiency: the avoided-cost benefits of efficiency and retail rates.

8.2 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 all program funding scenarios were not cost-effective under the Low energy cost scenario. As discussed in Sections 7, all of the program funding scenarios under Base and High energy costs had total resource cost (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.

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, especially 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 explicitly 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 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 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 stated in Section 1, the scope of this report focused on the retrofit of existing buildings. 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, key uncertainties include the following:

- *All end uses*. Estimates of the current saturation of energy-efficiency measures in existing commercial buildings is outdated as they are generally based on commercial end-use surveys (CEUS) that were conducted in the mid-1990s. The new CEUS currently being conducted should provide updated measure saturation estimates.
- *Space heating*. Much of the savings estimates for space heating were taken from the DEER database (NEOS, 1994). These estimates are based on DOE-2 simulation but are available for only 14 building prototypes. Savings vary widely across these prototypes, partly due to factors such as aggregation bias. New research is needed to refine savings estimates for natural gas heating measures.

[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.

- *Water heating*. The available savings estimates used for the water heating end use tend to be based on engineering-based judgment and reflect rough averages of savings across building types. It was difficult to accurately link measure savings to measure costs because specific estimates of retrofit effort were not tied to the savings estimates. Well-documented water heating consumption prototypes should be developed that clearly match incremental cost, savings, and unit intensity assumptions (e.g., the number of linear feet of pipe per square foot on building that would be insulated in a retrofit).
- *Pool heating*. Few existing sources disaggregate pool-heating consumption from the miscellaneous end use, and rough estimates tied to PG&E and SDG&E CEUS studies were developed for this project. Additionally, the fraction of pools for which pool covers are feasible and actively used is currently uncertain.

8.3 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. 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. An upcoming study is expected to address permanent efficiency improvements in 2001 (and 2002) and any sustained conservation behavior.
- ***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 in the commercial sector (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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