Electric Efficiency in California's Industrial Sector: The Potential Gap

Michael Rufo, Quantum Consulting, Inc.
Rafael Friedmann, Pacific Gas & Electric Company
Fred Coito, KEMA-XENERGY

ABSTRACT

This paper presents estimates of potential electricity and peak demand savings from energy-efficiency measures in California's industrial sector. The results presented are a preliminary product of the first and second of a series of studies being conducted in California to improve understanding of the potential for industrial efficiency savings and estimate the current market penetration of efficiency measures. Initial forecasts of achievable savings and associated costs are provided for different levels of program funding over a 10-year period. Program savings and cost-effectiveness estimates are also evaluated under several possible future scenarios that take into account uncertainty in electricity rates and wholesale energy costs. We compare estimates of achievable potential to projected business-as-usual industrial program savings. Weaknesses in the current research also are discussed. We conclude with suggestions for improving the accuracy and usefulness of California industrial potential estimates through coordination and integration of the remaining sector studies and other related research.

Background

California's Renewed Interest on Efficiency Resource

The recent electricity crisis in California led policy makers, utilities, planners, and the public to revisit the role that energy efficiency can play in heading off or minimizing the impacts of such crises in the future. For over two decades, California was a leader in energy planning and was among the first states to formally recognize the value of energy efficiency. The State made some of the largest strides in treating energy efficiency as an energy resource and went far toward institutionalizing efficiency as a viable alternative to conventional energy sources. In response to the market-oriented electricity restructuring process embarked on in California in the mid-1990s, formal resource planning in which energy efficiency could compete against conventional supply-side alternatives was abandoned. As a result, efficiency programs languished in the period just prior to the California energy crisis. Fortunately, enough of the efficiency infrastructure was left in place to allow the state to rapidly ramp up energy-efficiency expenditures in 2000 and 2001. These efforts, combined with conservation efforts and regulatory interventions, helped tamed the crisis (Goldman, Eto, and Barbose, 2002). Within this context, the California Public Utilities Commission, the California investor-owned utilities (IOUs), and the Energy Foundation conducted a number of studies estimating the remaining potential for energy efficiency in the state.

California IOU's Industrial Research Plan

As noted above, the results presented in this paper are drawn principally from the first and second of a planned series of studies. These studies are designed as a suite of research activities working in consort to increase understanding of the state's industrial market characteristics, decision-making processes, segment needs, efficiency penetration rates, and the potential for increased adoption of energy efficiency. The key studies that comprise the overarching research plan and their planned sequence and objectives are shown in Table 1.

Table 1. Summary of Key Studies in California IOU Industrial Research Portfolio

Study	Scope	Managing Organization	Completion Date
Large Customer Wants and Needs (QC 2000)	In-depth, qualitative analysis of key decision-making drivers for selected market segments	SCE (all IOU scope)	2001
California Industrial Market Characterization (XEN 2001)	Uses secondary source data to organize and segment energy use, identify primary energy efficiency opportunities, and integrate program accomplishments	PG&E (all IOU scope)	2001
California Energy Efficiency Potential Study (XEN 2002)	Bottom-up analysis of efficiency potential. Industrial sector results highly aggregated, tied to limited number of secondary sources.	Energy Foundation	2002
California Small/Medium Industrial Study (QC 2003)	Analysis of the under 500 kW industrial market. Includes quantitative phone survey of this population.	PG&E (all IOU scope)	Spring 2003 (draft is complete)
California Nonresidential Market Share Tracking Study	Collecting primary data on energy efficiency market share for industrial and commercial equipment and practices.	CEC (all IOU scope)	Fall 2003
California Industrial Case Studies	In-depth case studies of efficiency-related decision-making and benchmarking for 5 segments.	PG&E (all IOU scope)	Fall 2003
Updated California Industrial Potential Analysis	Update of California Industrial Potential estimates incorporating results from all available studies.	PG&E (all IOU scope)	Late 2003

The estimates of industrial sector load presented in this paper were developed in the California Industrial Market Characterization Study. The estimates of efficiency potential are based on results from the California Energy Efficiency Potential Study.

Scope and Approach

The estimates of California industrial potential presented here are the result of a limited scope effort. The analysis was carried out as part of a larger study of efficiency potential in all sectors. Although a bottom-up methodology was used, many of the key data inputs were obtained from secondary sources. In addition, the analysis was conducted at a highly aggregated level – the industrial sector was segmented into only large (over 500 kW) and small customers. End use estimates were developed at the 2-digit SIC level (XEN 2001); however, the end use estimates were then aggregated to the level of all large and small customers for the efficiency potential analysis.

The integration of efficiency measure characteristics (incremental costs, savings, and saturations) with baseline usage data occurred in two ways. For lighting, HVAC, and motor efficiency and VSDs, costs and savings were developed directly, that is, we were able to specify costs in terms of dollars per fixture, ton of cooling, or horsepower of motor capacity, as examples. For motor practices, compressed air, and the process end use, costs and savings were derived indirectly from secondary sources. For these cases, we aggregated and estimated the costs and savings opportunities into small sets of measure bundles. For example, all of the motor practice opportunities were bundled into two levels – Motor Practices Level 1 and Motor Practices Level 2 (with costs and savings incremental to Level 1). For compressed air and process, three bundled levels of efficiency were developed for each end use, with each level incremental to the previous level. The key secondary sources used for each of these measure areas were as follows: motor practices (XENERGY 1998), compressed air (XENERGY 2000), and process (Martin, et al., 1999 – 2000a and Worrell, et al., 1999-2000). Only in the case of the process end use sources were actual efficiency supply curves available, though only for three industries. In this case, we essentially aggregated the detailed LBNL supply curves into three-step supply curves, with each step being an efficiency level. We then averaged the three-step curves across the three industries. In the case of motor practices and compressed air, the secondary information available was more qualitative. The secondary sources provided only rough guidance for estimating ranges of savings as related to costs (generally expressed only in terms of payback ranges).

Although far from ideal, integration of the primary California usage data with the secondary information on industrial sector opportunities was the only viable path for rapidly developing a preliminary estimate of the total industrial potential in the state. Nonetheless, we recognize the current work suffers from two key weaknesses. First, the measure opportunity data used may not be precisely applicable to the specific mix of industries in the state and, second, significant aggregation bias may exist because the analysis was not carried out at an industry-specific level and because individual measures were consolidated into bundles, as discussed above.

Our industrial potential analysis includes estimates of several types of potential common to such studies. The potentials estimated and our definitions for them are as follows: **Technical potential** is defined in this paper as the *complete* penetration of all measures analyzed in applications where they were deemed *technically* feasible from an *engineering* perspective. **Economic potential** refers to the *technical potential* of those energy conservation measures that are cost effective when compared to supply-side alternatives, using the total resource benefit-cost test. **Achievable potential** refers to the amount of savings that would occur in response to specific program funding and measure incentive levels. Savings associated with program potential are savings that are projected beyond those that would occur naturally in the absence of any market intervention. **Maximum achievable potential** is defined as the amount of economic potential that could be achieved over time under the most aggressive program scenario possible. **Naturally occurring potential** refers 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. Specific achievable potential scenarios are described below.

The results in this paper are restricted to energy-efficiency measures and practices that are presently commercially available. We present results for only the existing stock of industrial facilities. Also, note that the analyses for this paper were conducted in 2001 and early 2002, a time characterized by unprecedented changes in energy consumption and behavior among consumers and businesses in California in response to the energy crisis. As a result, the estimates of potential presented in this paper do not reflect the unusual level of energy conservation and efficiency that occurred in 2001. The effects of 2001 were not well enough understood to incorporate into the research at the time that the primary analyses were conducted. Future updates of this work should incorporate revised energy consumption baseline information that accounts for any permanent changes in conservation and efficiency resulting from the recent energy crisis.

The crux of our analysis involves carrying out a number of basic analytical steps to produce estimates of the energy-efficiency potentials introduced above. The bulk of the analytical process for this work was carried out in a model developed by XENERGY for conducting energy-efficiency potential studies. The model 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. A supply curve approach is used to estimate technical and economic potential, with measure sorting and economic potential defined by the total resource cost benefit-cost test[1] (TRC). Using the TRC is advantageous because the value of both energy and peak demand savings are incorporated into the analysis. The adoption modeling approach uses a two-step process in which end users must be aware and knowledgeable about each efficiency opportunity before adopting it and, once aware, adopt at a market share level determined by the economic attractiveness of the measure and level of market barriers associated with it. Details on the steps employed and analyses conducted are described in XENERGY 2002a and XENERGY 2002b.

Efficiency Potential Scenarios

We constructed 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, our estimates of potential depend on estimates of measure availability, measure costs, measure

[1] The TRC is a benefit-cost test used by utilities and regulators in California and many other states as a measure of societal cost-effectiveness. The numerator of the test includes energy-related benefits as measured by avoided energy generation, capacity, and transmission and distribution costs. The denominator of the test includes all direct costs including both participant and program costs. An 8 percent nominal discount rate was used in the benefit-cost calculations (this is the rate currently used by the California Public Utilities Commission when it assesses efficiency program cost-effectiveness).

savings, measure saturation levels, electricity 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. Second, the final quantity with which we are most interested in this paper, achievable potential, is by definition amenable to policy choices. 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. 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 electricity prices and future program funding levels. As a result, we limited the scenario analyses for our work to these two dimensions. Each dimension, energy cost and funding level, is referred to as a scenario *element*. As discussed below, we developed three energy cost elements (Base, Low, and High) and three program funding level elements (Business-as-Usual, Advanced Efficiency, and Maximum Achievable Efficiency). These elements are then combined into nine achievable potential scenarios. The elements of the scenarios are summarized in Tables 2 through 4.

Table 2. Summary of Base Energy Cost Element

Cost Type	Description	Source
Avoided Costs	Annual energy avoided-cost averages roughly 7 cents per kWh saved. Avoided costs for transmission and demand equal roughly 1.5 cents per kWh saved.	CPUC authorized avoided costs for major IOU's 2001 cost-effectiveness analyses (CPUC 2000)
Rates	Current industrial rates decrease to return to nominally normal levels by 2006.	CEC's California Energy Outlook 2002-2012. (CPUC 2001 and 2002)

Table 3. Summary of Low and High Energy Cost Elements

	Energy Costs Element	
Cost Type	**Low**	**High**
Avoided Costs	50 percent lower than Base energy avoided costs. Average 3.5 cents per kWh saved for energy (5 cents per kWh saved total including 1.5 cents per kWh saved for transmission and distribution).	25 percent higher than Base energy avoided costs. Average 9 cents per kWh saved for energy (10.5 cents per kWh saved total including 1.5 cents per kWh saved for transmission and distribution).
Retail Rates	1998 frozen rates escalated by inflation.	Current actual rates that persist throughout forecast period on a nominal basis.

Table 4. Summary of Estimated Industrial Program Expenditures by Scenario (Average Expenditures Over the 10-Year Analysis Period in Millions of $ per Year)

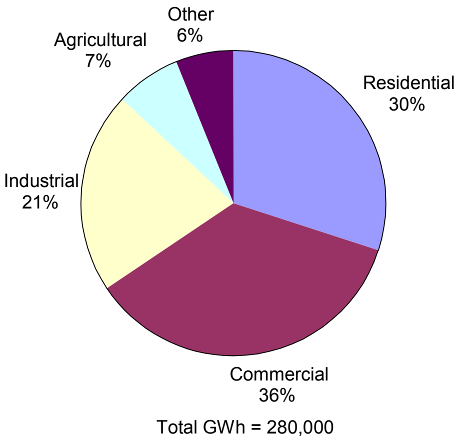
	Cost Components				
Funding Level	**Marketing**	**Administration**	**Incentives**	**Total**	**Average % of Measure Cost Paid***
Business-as-Usual	$5	$3	$12	$19	40%
Advanced Efficiency	$7	$5	$30	$42	66%
Maximum Efficiency	$18	$23	$167	$208	100%

*This refers to the fraction of incremental measure costs paid for by an efficiency program in the form of incentives.

Baseline Usage

To understand and estimate the potential for further efficiency improvements in California's industrial electrical energy use, it is important to understand how electricity is used in the State. Electricity use in California has long been dominated by the residential, commercial, and industrial sectors, as shown in Figure 1. The industrial sector in California is the smallest of the big three sectors, but is still a very significant contributor at 21 percent of total annual energy usage. As a percent of the state's total summer peak demand, the industrial sector represents 17 percent of the total.

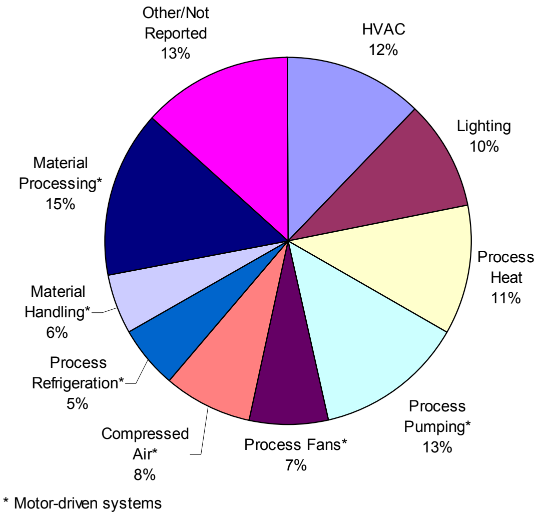
Figure 1. Breakdown of California Electricity Use by Sector: 2000



Our estimates of the breakdown of industrial energy use in California by end use are shown in Figure 2. For the manufacturing industries (SICs 20-39), end use energy consumption estimates are available from the Manufacturing Energy Consumption Survey (MECS). MECS provides end use split estimates for all 2-digit manufacturing SICs and for selected 3-digit and 4-digit SICs. The most recent MECS data, reflecting consumption in 1998 are now being provided using NAICS, the North American Industrial Classification System. These data were available too late to be included in this study. Instead data from the 1994 MECS are utilized.

To develop California-specific end use estimates, the MECS end-use splits were applied to California billing data consumption, first at the 4-digit level where MECS 4-digit splits were available, then at the 3-digit level and then the 2-digit level for consumption in remaining 3-digit and 4-digit SICs not directly covered in the MECS. For example in SIC 29 – Petroleum and Coal Products, the MECS data contain end use energy estimates for all of SIC 29 and for SIC 2911 (Petroleum Refining). The MECS end use splits for SIC 2911 were first applied to the California billing data for SIC 2911. Then the MECS end use splits for SIC 29 minus SIC 2911 were applied to the remainder of the SIC 29 billing data.

Figure 2. Estimated California Manufacturing Energy End-Use Breakdown



Source: U.S. DOE Manufacturing Energy Consumption Survey, Utility Billing Data, and XENERGY analysis.

Large customers dominate energy use in California's industrial sector. Table 5 shows the breakdown of small and large sites in the California industrial sector. For electricity, large sites with electric demand of 500 kW or more account for about 4% of the sites, 74% of the kWh consumption, and 73% of the kW demand. The largest 1,000 electric sites account for about two-thirds of total industrial electric consumption. The very small industrial customers, with demand less than 50 kW, comprise over 70% of all industrial sites but account for less than 10% of industrial electricity consumption.

Table 5. California IOUs' Industrial Small-Large Site Breakdown

	Electric		
	Sites	**GWh**	**MW**
Small	71,502	8,974.7	2,059.6
Large	2,766	24,920.6	5,561.3
% Large	4%	74%	73%

Large electric customers are defined as using more than 500 kW.
Source: CA IOU Utility Billing Data

Key Findings

If all measures assessed were implemented where technically feasible, we estimate that overall technical peak demand savings would be close to 2,300 megawatts (MW), as shown in Figure 3. If all measures that are economic were implemented, potential peak demand savings would amount to roughly 1,500 MW. Estimated technical and economic energy savings are roughly 12,500 GWh and 8,300 GWh, respectively, as shown in Figure 4. These savings are approximately 16% (technical potential) and 11% (economic potential) of total industrial energy consumption. A common way to illustrate the amount of energy-efficiency savings available for a given cost is to construct an energy-efficiency supply curve. Our electric energy-efficiency supply curve for California's industrial sector is shown in Figure 5.

The industrial sector is notoriously heterogeneous, being composed of hundreds of different types of manufacturing, production, and assembly plants for thousands of different products. Our estimated distribution of economic industrial sector potential is shown by end use in Figures 6 and 7. The relative mix of end-use savings is fairly similar for both energy and peak demand. Motor and process applications account for the majority of potential savings (58%), followed by lighting (23%), compressed air (11%), and space cooling (8%). These savings follow somewhat proportionally from the distribution of base consumption; however, lighting savings are higher as a proportion of base consumption as compared with other end uses.

As we discussed above under Scope and Approach, we used a small set of key sources as the basis for the measure cost and savings inputs to our analysis, primarily the industry-specific efficiency potential studies conducted by Lawrence Berkeley National Laboratory (Martin, et al., 1999 – 2000a and Worrell, et al., 1999 - 2000), the California industrial market characterization study (XENERGY 2001) and two recent national Department of Energy studies (XENERGY 2000 and 1998). Details on industrial savings opportunities can be found in these references. Examples of key measures include variable-speed drive motor and pump applications, proper motor and pump sizing, redesign of pumping systems to reduce unnecessary flow restrictions, improved operations and maintenance, reducing compressed air system leaks, and optimizing compressed air storage configurations. Lighting and space cooling savings measures are similar to those in the commercial sector (see XENERGY 2002a).

Because achieving efficiency savings requires programmatic support, we estimated savings under several future investment scenarios. As shown in Figure 8, for 10 years worth of programs, net program savings range from roughly 1,200 GWh/year under current funding (Business-as-Usual) to 2,500 GWh/year if funding is doubled (Advanced Efficiency), to 7,500 GWh/year if all of the possible achievable potential was obtained (requiring an estimated 10-fold increase in program funding). Under Business-as-Usual funding, cumulative savings by year ten amount to only about 1.5% of year 2000 industrial consumption, while under the Advanced and Maximum Efficiency cases savings increase to roughly 3% and 9%, respectively, of year 2000 consumption.

Figure 3. CA Industrial Technical and Economic Potential Peak Demand Savings—MW

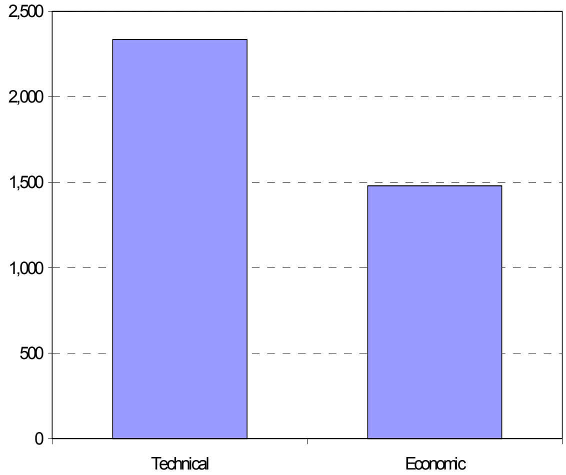


Figure 4. CA Industrial Technical and Economic Potential CA Energy Savings—GWh per Year

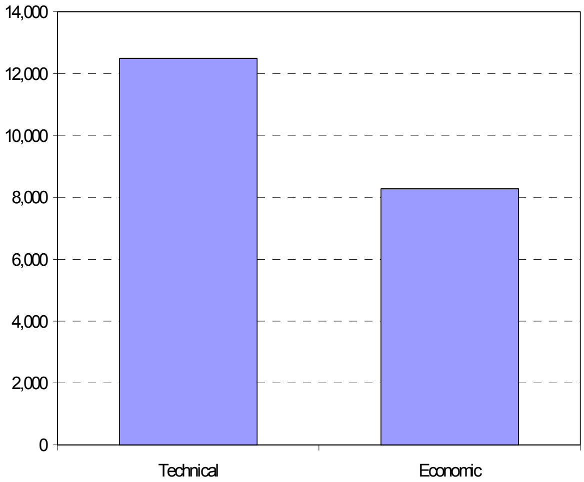
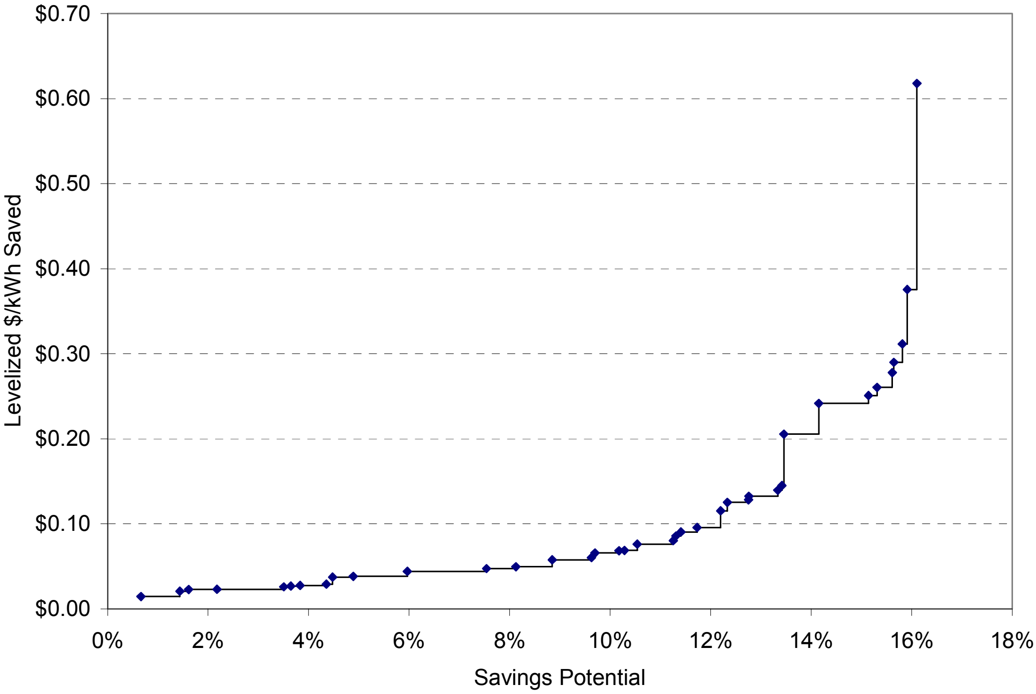


Figure 5. CA Industrial Energy-Efficiency Supply Curve



*Levelized cost per kWh saved is calculated using an 8-percent nominal discount rate.
For measure-level result details see XENERGY 2002b.

Figure 6. Industrial Economic Demand Savings Potential by End Use

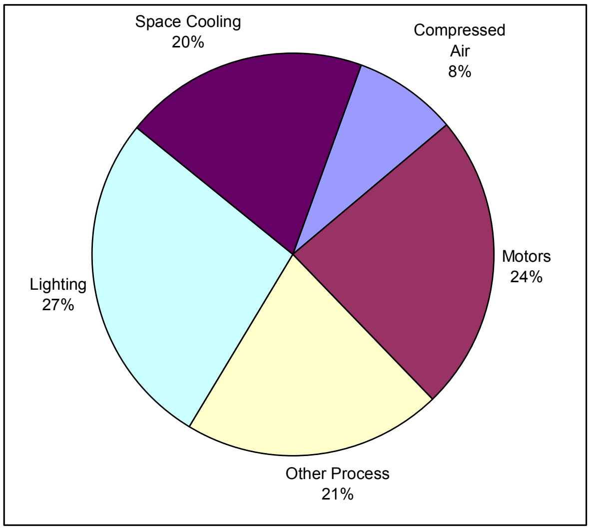


Figure 7. Industrial Economic Energy Savings Potential by End Use

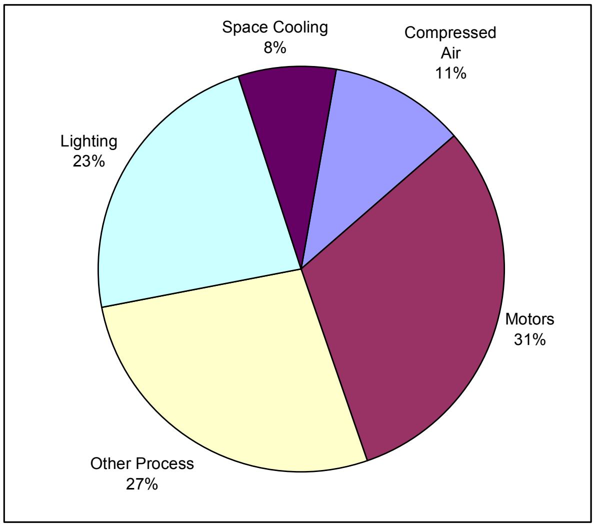
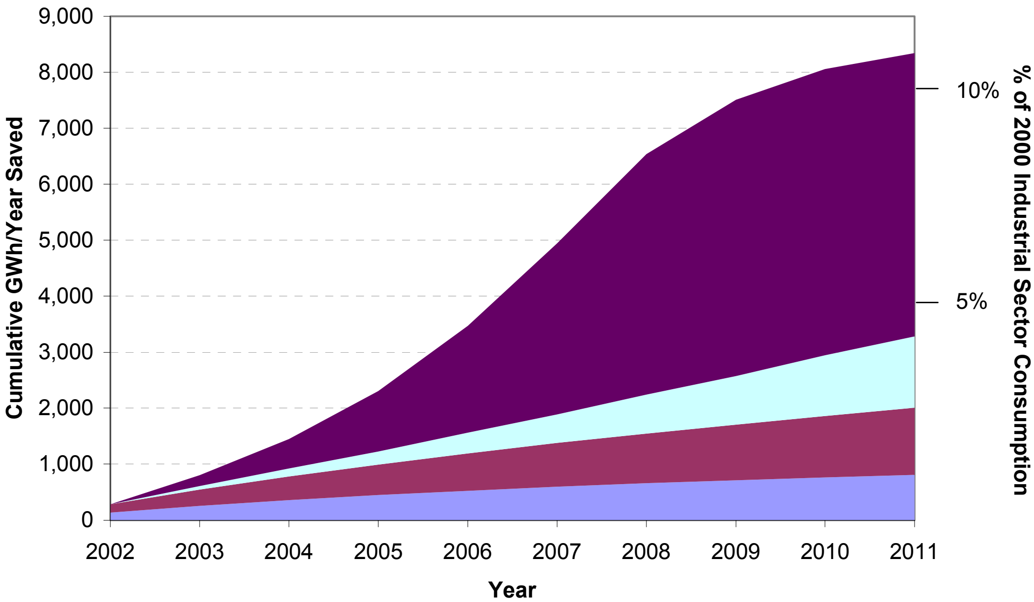


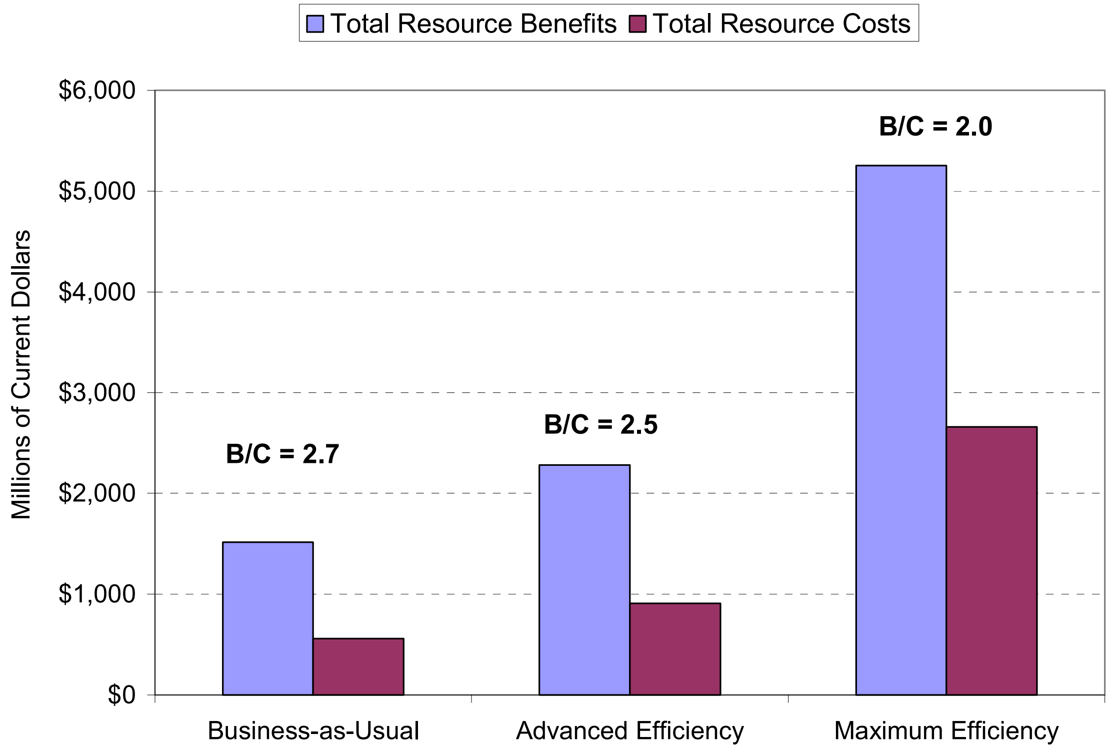
Figure 8. Potential CA Industrial Efficiency Savings by Funding Scenario



We estimate that more than $193 million would be spent on public goods programs to promote industrial efficiency in California over the next 10 years if current efficiency program spending levels continue—an investment projected to yield roughly $1.5 billion in savings. As shown in Figure 9, we estimated that by doubling the amount spent on such programs, the state could save over $2.3 billion on electricity costs, at a net savings of $1.4 billion. If all of the 10-year achievable potential were captured, savings would exceed $5 billion, with net benefits of $2.6 billion.

All of the funding scenarios forecasted are cost effective based on the total resource cost (TRC) test, which is the principal test used in California to determine program cost effectiveness. The TRC benefit-cost ratios (under the Base energy cost forecast) are 2.7, 2.5, and 2.0 for the Business-as-Usual, Advanced Efficiency, and Max Efficiency scenarios, respectively. Savings and benefit-cost ratios are presented for each of the energy cost scenarios in Figure 10 and Table 6. Savings under the Low Energy Cost scenario are only roughly 12% below the Base Energy Cost scenario results for the Business-as-Usual and Advanced Efficiency cases. Benefit-cost ratios for the Low Energy Cost scenario are much lower than the Base ratios, though still positive, ranging from 1.5 to 1.3.

Figure 9. Benefits and Costs of CA Industrial Electric Energy-Efficiency Savings



*Present value of benefits and costs over 20-year normalized measure lives for 10 program years (2002-2011), nominal discount rate = 8 percent, inflation rate = 3 percent.

Figure 10. California Net Achievable Industrial Energy Savings by Energy Cost Scenario

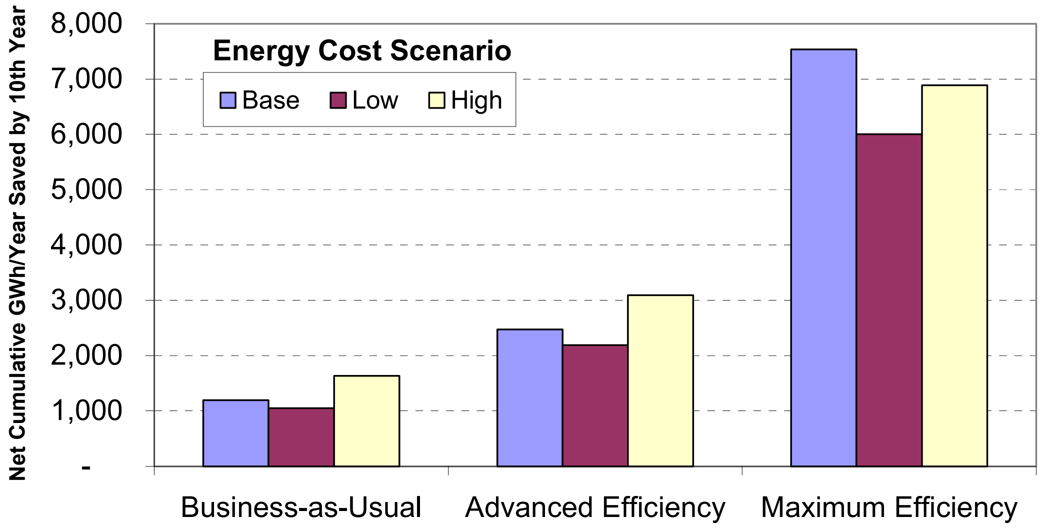


Table 6. TRC Ratios by Cost Scenario

Cost Scenario	Funding Level		
	Business as Usual	**Advanced Efficiency**	**Max Efficiency**
Low	1.6	1.5	1.3
Base	2.7	2.5	2.0
High	3.2	3.0	2.4

Conclusions

As noted previously, we consider the results presented in this paper to be preliminary as they were developed on a limited project with limited resources. Nonetheless, there appears to be a very large gap between our estimates of economic potential and our forecast of Business-as-Usual achievable potential. Particularly as compared with our parallel commercial sector analysis (see XENERGY 2002a), only a small percentage of the economic potential in the industrial sector is likely to be captured under the Business-as-Usual funding level. Capturing the additional achievable potential would require a significant increase in public goods funding.

Although some of the potential savings are obtainable from energy-efficiency measures that are well understood, significant savings are tied to process measures and practices that require extensive further analysis before firm conclusions can be drawn. In particular, more specific data is needed on the costs and savings of some measures (particularly, compressed air and motor practices), while in the case of the process end use more work is needed to tie process measure costs, savings, and applicability developed in national studies to the specific industrial facilities that comprise the California market.

Additional research also is needed on the costs and savings for the process end use of major industrial segments that were not included in the LBNL supply-curve studies in the 1990s.

The California industrial research projects listed in Table 1 have been designed to fill some of the research gaps identified above in order to improve the accuracy, defensibility, and usefulness of industrial potential estimates. In addition, however, national and collaborative research is needed to further refine and improve the characterization and cross-study transferability of industrial measure costs, savings, market penetration, and applicability. An update to the preliminary analysis presented in this paper is planed for late 2003.

References

California Energy Commission, unpublished spreadsheet: "Summary of Electric DSM Impacts and Funding."

California Energy Commission (CEC). 2002. *California Electricity Outlook 2002-2012,* P700-01-004, Final Report, February.

California Energy Commission (CEC). 2001. *California Electricity Outlook 2002-2012,* P700-01-004, Draft Final, December.

California Public Utilities Commission (CPUC). 2000. *Ruling on Cost-Effectiveness Issues*, Administrative Law Judge Linda R. Bytoff, October 25, 2000, A.99-09-049.

CA SPM 2001. *California Standard Practice Manual. 2001.* California Public Utilities Commission and InterAgency Green Accounting Working Group, October 2001.

Goldman, Charles, Joseph Eto, Galen Barbose. 2002. *California Customers Load Reductions During the Electricity Crisis: Did They Keep the Lights On?* Lawrence Berkeley National Laboratory, LBNL-49733, May.

Martin, N., Anglani, N., Einstein, D., Khrushch, M., Worrell, E., and L. Price. 2000a. *Opportunities to Improve Energy Efficiency and Reduce Greenhouse Gas Emissions in the US Pulp and Paper Industry.* Ernest Orlando Lawrence Berkeley National Laboratory. Berkeley, CA. July.

Martin, N., Worrell E., Ruth, M., Price, L., Elliot, R. N., Shipley, A. M., and J. Thorne. 2000b. *Emerging Energy-Efficient Industrial Technologies.* Ernest Orlando Lawrence Berkeley National Laboratory. Berkeley, CA. October.

Martin, N., E. Worrell, and L. Price. 1999. *Energy Efficiency and Carbon Dioxide Emissions Reduction Opportunities in the US Cement Industry.* Ernest Orlando Lawrence Berkeley National Laboratory. Berkeley, CA. September.

Quantum Consulting, Inc. 2001. *Large Customer Needs and Wants Study*, prepared for Southern California Edison Company. January.

Worrell, E., Martin, N., D. Einstein, and D. Phylipsen. 2000. *Energy Use and Energy Intensity of the US Chemical Industry.* Ernest Orlando Lawrence Berkeley National Laboratory. Berkeley, CA. April.

Worrell, E., Martin, N., and L. Price. 1999. *Energy Efficiency and Carbon Dioxide Emissions Reduction Opportunities in the US Iron and Steel Sector.* Ernest Orlando Lawrence Berkeley National Laboratory. Berkeley, CA. July.

Worrell, E., Martin, N., and L. Price. 1998. *Energy Efficiency Opportunities in Electric Arc Steelmaking.* Ernest Orlando Lawrence Berkeley National Laboratory. Berkeley, CA. November.

XENERGY, Inc. 2002a. *California Commercial Sector Energy-Efficiency Potential Study (Existing Construction Only)*, prepared for Pacific Gas and Electric Company, July.

XENERGY, Inc. 2002b. *California's Secret Energy Surplus: The Potential for Energy Efficiency,* prepared for The Energy Foundation as part of the Hewlett Foundation Energy Series, September.

XENERGY, Inc. 2001. *California Industrial Sector Market Characterization Study*, prepared for Pacific Gas and Electric Company.

XENERGY, Inc. 2000. *Assessment of the Market for Compressed Air Efficiency Services*, prepared for United States Department of Energy, Washington, D.C. August.

XENERGY, Inc. 1998b. *United States Industrial Motor Systems Market Opportunities Assessment,* prepared for the Office of Industrial Technologies and Oak Ridge National Laboratory, U.S. Department of Energy. December.