Examining the Peak Demand Impacts of Energy Efficiency:
A Review of Program Experience and Industry Practices

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February 2007

Report Number U072

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ACKNOWLEDGMENTS

We gratefully acknowledge and thank our project sponsors: National Grid USA, the New York Energy Research and Development Authority (NYSERDA), Pacific Gas & Electric, Sempra Utilities, and Southern California Edison. This project would not have been possible with their support, guidance, and input. We thank Susanne Brooks of ACEEE for reviewing and gathering data from the databases and technical references used in this project. We also thank Ed Vine for reviewing evaluation practices and preparing selected case studies. We also thank Harvey Sachs, Steven Nadel, Bill Prindle, and Neal Elliott of ACEEE for project and technical guidance. Finally, we thank ACEEE's editor, Renee Nida, for editing and producing this final report.

EXECUTIVE SUMMARY

Over two decades of experience with "demand-side management" (DSM) and related programs addressing customer energy use has demonstrated clearly that customer demand is indeed a variable that can be affected through utility and other types of programs. The two primary types of DSM programs—energy efficiency and load management—have historically had relatively different core objectives. Energy efficiency programs primarily seek to reduce customer energy use (kilowatt-hours or kWh) on a permanent basis through the installation of energy-efficient technologies. Load management, by contrast, generally focuses on either curtailing or shifting demand (kilowatts or kW) away from high cost, peak demand periods. The relative costs and benefits of each main type of program vary from utility to utility.

There are obvious overlaps between energy efficiency and load management. Reducing peak demands may also yield energy (kWh) savings, and most energy-efficient technologies also yield some peak demand savings. While energy efficiency programs can and often do produce reductions in peak demand (measured in kW), such impacts historically have not been an area of priority focus for such programs. The focus on energy savings impacts also has affected evaluation priorities. The primary emphasis has been on estimating the energy (kWh) savings that have resulted from the programs. Quantifying the peak demand impacts generally has not been a high priority for evaluation, and practical limitations, such as the general lack of time-differentiated customer end-use data, also have limited efforts to estimate such impacts.

Over the past decade, however, increased concerns about electric system reliability have combined with concerns about the cost of new generation and transmission and distribution (T&D) investments to create a renewed interest and need for energy efficiency to be able to reduce peak demands as well as reduce overall energy use. Because energy efficiency produces a number of additional benefits that load management alone does not, there is an understandable desire to use energy efficiency as a first priority resource to address both demand and energy resource needs…**if** energy efficiency can be shown to produce reliable peak demand reductions. This has led to a growing interest in being able to quantify the effects of energy efficiency on system peak demand.

In this study we reviewed experience with peak demand savings from energy efficiency programs. In our review we examined selected program results and experience. We sought to identify examples of energy efficiency programs that have achieved clear, significant peak demand savings. Certain states and regions have achieved significant—even dramatic—peak demand savings from energy efficiency, such as California during its 2000–2001 electricity crisis.

In the process of examining various state and regional examples, we selected thirteen programs as case studies of programs that have achieved significant peak demand savings via energy efficiency. These case studies clearly illustrate that energy efficiency programs can yield measurable, significant peak demand savings. The case studies also demonstrate the

evaluation approaches and techniques necessary to measure and quantify peak demand impacts.

Quantification of the energy and demand impacts of energy efficiency and other DSM programs is central to relying on these programs as viable resources within utility resource portfolios and energy markets. Energy program evaluation employs a variety of tools and approaches to measure and quantify such impacts. The science and practice of energy program evaluation has developed hand-in-hand with the programs themselves. Energy program evaluation professionals and key stakeholders have developed industry protocols for approaches, specific techniques, and standards of professional practice for quantifying energy program impacts. Two leading examples of energy program evaluation protocols are: (1) *The International Performance Measurement & Verification Protocol* and (2) *Evaluators' Protocols, California Public Utilities Commission.*

Estimating the demand impacts (kW) from energy efficiency and other programs often builds on the estimates of energy savings impacts. This is true for a number of reasons, many having to do with the availability and costs of data. Energy use data (kWh) are readily available from customer billing data on electricity consumption. In contrast, utility metering of customer power demand or time-of-use is not routine, particularly for residential and small commercial/industrial customers. Consequently, estimating peak demand impacts of energy efficiency often involves application of various load shapes and load factors, which are developed as the result of customer load research used most typically for load forecasting and system operations.

To examine evaluation trends relative to measurement of peak demand impacts of energy efficiency programs, we reviewed two key sources within the energy efficiency program industry: the conference proceedings for the International Energy Program Evaluation Conference (IEPEC) from 1993–2005 and the ACEEE Summer Studies on Energy Efficiency in Buildings from 1994–2006. One of the most important findings in this review was the small number of energy efficiency studies that documented demand impacts in the fourteen years of conference proceedings. Whereas energy savings (kWh) were commonly provided in the energy efficiency evaluations, demand savings were established much less often. Another related key finding is the change in these numbers over time. In the early '90s we found a relatively large number of papers directly on this topic—but as the '90s proceeded, we found fewer and fewer such papers. Published papers in this latter period tended to rely on applying load curves (developed in the '80s and early '90s) to the estimated energy (kWh) impacts, rather than using metered demand data specific to the program being evaluated. These findings reflect evaluation priorities, and technical and cost issues associated with estimating peak demand impacts.

With the renewed interest and use of energy efficiency as a resource, the importance of estimating both energy and demand impacts accurately is increasing. Emerging market structures and transactions that allow demand resources to participate in energy markets similarly will increase the importance of accurate estimation of these resources.

The expanding use of more advanced customer metering technology will facilitate the use of demand data in program evaluations. New and expanded use of advanced metering technologies also may help address cost issues associated with estimation of peak demand impacts. As utilities increase the number of customers with time-of-use meters in place for routine billing purposes, program evaluators will be able to use this time-differentiated usage data without the need to install separate, dedicated metering and logging equipment.

There well may be an advantageous convergence of need, capabilities, and costs emerging for estimating peak demand impacts. As utilities and system operators rely more and more on demand-side options to address peak demand and related reliability concerns, their needs for accurate and timely quantification of demand-side impacts increases commensurately. Parallel with these trends are rapid increases in the capabilities of monitoring and communications technologies that can yield relatively low costs for data gathering and analysis. It will be important for utilities and regulators to work with the program evaluation community to address these issues and weigh the many factors that go into developing evaluation plans, including program objectives, evaluation priorities, budgets, costs, capabilities, and needs.

A final objective of this project was to create a practical comparative database of estimated peak demand impacts for selected energy efficiency measures. The purpose of this component of the project was to create a simple and practical information resource that program planners and evaluators could access to obtain reasonable "representative" estimates of the peak demand impacts of common energy efficiency measures, for use in initial program design and assessment.

We began this aspect of the project with a review of leading technical references used to estimate energy and peak demand impacts of energy efficiency measures, which in several cases take the form of electronic databases. We conducted a search to identify databases and similar technical references that are used by leading utility-sector energy efficiency programs. From this review we selected the following databases and technical references to use in the creation of a comparative database of selected energy efficiency measures:

- *Database for Energy Efficiency Resources* (DEER). California Energy Commission.
- *Deemed Savings Database, Version 9.0.* New York State Energy Research and Development Authority.
- *Deemed Savings, Installation & Efficiency Standards: Residential and Small Commercial Standard Offer Program, and Hard-to-Reach Standard Offer Program.* Public Utility Commission of Texas.
- *Conservation Resource Comments Database.* Northwest Power and Conservation Council.
- *Technical Reference User Manual* (TRM). Efficiency Vermont.

To compare data across these references we identified a set of common end-use energy efficiency measures included in programs. We then collected data on these measures from each of the technical references and databases to create a comparative database. The purpose of this review and collection of data is to illustrate the types of measures commonly included in utility sector program databases. In these examples we also sought to show typical values used for peak demand and energy savings associated with specific measures with data drawn from the databases we selected for inclusion in this review. Our comparative database should be viewed as a selected detail from a much larger picture. The data we compiled and report are really starting points for program design, implementation, and evaluation. The data could readily be used at the program scoping and development stage for certain types of programs.

In reviewing these databases we found that the measures for which it is possible to have the most uniform definition (for example, residential 15 watt compact fluorescent light bulb replacing a 60 watt incandescent) show the most uniformity in terms of reported energy and demand savings. Other measures that were not as uniformly defined (for example, variable speed motor drives or packaged rooftop HVAC units) tended to show wider variations. Similarly, measures that are climate sensitive also tend to show wider variations, as would be expected. The databases and technical references are most useful for fairly well-defined, "standard" measures. Energy efficiency measures that involve more complex or customized services generally require a project-specific estimation of energy and demand savings; standardized or deemed savings estimates are not well suited to such applications. We found that generally the databases provide reasonably good documentation of the data references and key assumptions. This is critical to allow ready checking on the source and accuracy of reported data and to understand key assumptions. It also easily allows updating and comparison to other references.

Our major findings in this study are:

- Energy efficiency programs clearly have achieved significant peak demand reductions. We found examples of clear, well-documented estimates of such impacts from individual measures, entire programs, and entire state and regional utility systems.
- While we found well-documented estimates of peak demand impacts of energy efficiency, most program evaluations have not used direct, on-site measurement of the demand impacts. Rather, program evaluations typically have relied on customer billing or other measurements of kilowatt-hour use as primary data. Load shapes or load factors are then applied to these data to estimate the peak demand impacts.
- As utilities and system operators increase their use of energy efficiency programs as energy system resources to deliver both energy (kWh) and peak demand (kW) savings, the need for greater understanding and accurate quantification of the peak demand impacts of energy efficiency will increase.
- There are solid foundations in place for establishing a firmer, broader knowledge base of the peak demand impacts of energy efficiency. There are numerous technical references and databases in use that provide measure-by-measure quantification of these impacts and the professional evaluation community has well-established practices and protocols for addressing this growing need.
- There well may be an advantageous convergence of need, capabilities, and costs emerging for estimating peak demand impacts. Rapid increases in the capabilities of metering and communications technologies can yield relatively low costs for data gathering and analysis. Utilities and regulators will need to work with the program evaluation community to address emerging needs for program evaluation—weighing the

many factors that go into developing their evaluation plans, including new technological capabilities, program objectives, evaluation priorities, available budgets, and evaluation costs.

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1. INTRODUCTION

Background

In the late 1970s and into the 1980s, a quiet revolution occurred within the electric utility industry. This revolution was the development and practice of "demand-side management" (DSM) and "integrated resource planning" (IRP). The very premise of DSM is that there are benefits to both utilities and their customers to change energy use patterns, whether by shifting demand to different periods, reducing demand at specific times, or reducing overall energy use through energy-efficient technologies. DSM represented a dramatic shift in how utilities defined their business functions and how they responded to customer demands. Prior to DSM, customer demand was something considered outside the domain of utility influence and business operations. Utilities focused on the "supply side:" they planned, built, and operated their electricity generation, and transmission and distribution systems in response to actual and expected customer demand.

Over two decades of experience with DSM and related programs addressing customer energy use has demonstrated clearly that customer demand is indeed a variable that can be affected through utility and other types of programs.

The two primary types of DSM programs—energy efficiency and load management—have historically had fundamentally different main objectives. Energy efficiency programs seek to reduce customers' total energy use (kilowatt-hours) through energy-efficient technologies. Load management, by contrast, generally focuses on either reducing or shifting demand (kilowatts) away from high cost, peak demand periods. The relative costs and benefits of each type of program vary from utility to utility. Given the relatively high costs of meeting peak demands, most utilities readily have embraced some type of load management. A variant of load management, "demand response," has emerged over the past several years as a preferred option for many utilities, especially where competitive wholesale power markets are active. Such programs employ market-based approaches to elicit customer responses to high cost or constrained market conditions (York and Kushler 2005a).

Planning and implementing energy efficiency programs have generally met with greater resistance from utilities than have load management programs. Successful energy efficiency programs reduce electricity sales in kilowatt-hours (kWh), which can reduce utility revenues and associated profits. This barrier has been successfully overcome via numerous means since the advent of DSM—generally through a combination of effective regulatory treatment of utility energy efficiency program costs and utility management's acceptance of such programs as a key part of meeting customer needs and fulfilling their resource and business commitments. In more recent times, a growing number of utility-sector energy efficiency programs are provided by non-utility organizations under "public benefits" efficiency programs. Program operators in some public benefits programs are not utilities—they include state agencies, nonprofit organizations, and private contractors (Kushler, York and Witte 2004). In these cases, the "lost sales" disincentive to effective program delivery is absent because of this disconnection between utility electric service and non-utility efficiency program providers. A majority of public benefits programs, however, are administered by utilities. In these cases, several states address the "lost sales" barrier by providing "performance incentives" for achieving energy efficiency program goals and/or through "decoupling" of utility energy sales and revenues (Kushler, York, and Witte 2006).

There are obviously some overlaps between energy efficiency and load management. Reducing peak demands may also yield energy (kWh) savings, and most energy-efficient technologies also yield some peak demand savings. While energy efficiency programs can and often do produce reductions in peak demand (measured in kW), that has historically not been an area of priority focus for such programs. Prior ACEEE research has examined how energy efficiency can be used to reduce peak electrical demands and address electric system reliability concerns (Nadel, Gordon, and Neme 2000; Kushler, Vine, and York 2002). These studies provided clear examples that energy efficiency programs have yielded significant peak demand savings—savings that have been critical in addressing system reliability.

In evaluating the impacts of energy efficiency programs, the primary emphasis has been on estimating the energy (kWh) savings that have resulted from the programs. There have been two predominant reasons for this relative emphasis on estimating saved energy instead of related demand (kW) impacts. First, by their nature, energy efficiency improvements save energy at all times that the affected equipment operates, not just during times of electric system peak demand. Therefore, focusing on peak demand would miss most of the impact of the energy efficiency measures. Second, and more importantly, the lack of time-differentiated metering for the vast majority of customers meant that measuring program impacts using available utility billing data limited the analysis to total kWh consumption. In addition, engineering estimates of demand impacts from efficiency measures require judging the "coincidence" of efficiency measures on an hourly basis in relation to the system's peak load, as well as gauging the diversity of peak impacts from efficiency measures in many different customer installations, each of which may have different operating schedules. In Section 4 we discuss how the billing data limitation issue has affected evaluation practices for energy efficiency programs.

Over the past decade, however, increased concerns about electric system reliability have combined with concerns about the cost of new generation and T&D investments to create a renewed interest and need for energy efficiency to be able to reduce peak demands as well as reduce overall energy use. Because energy efficiency produces a number of additional benefits that load management alone does not,[1] there is an understandable desire to use energy efficiency as a first priority resource to address both demand and energy resource needs…**if** energy efficiency can be shown to produce reliable peak demand reductions. Using efficiency to moderate demand growth reduces the overall need for demand response; conversely, ignoring efficiency in building design and equipment replacement tends to oversize energy systems, needlessly driving up peak demand. This can create an artificial need for demand response, but sizing energy systems correctly as part of an efficiency program keeps the need for demand response in proportion.[2] These considerations have led

[1] These additional benefits from energy efficiency include: long-lasting energy and demand savings impacts; a reduction in total energy, consumption of energy resources, environmental emissions, and energy imports; etc.
[2] For example, air conditioning systems are routinely oversized unless efficiency programs are present to reduce cooling loads and train mechanical system designers and contractors to "right-size" equipment. A home that would need only three tons (nominally 3 kW of peak load) of air conditioning in an efficient design could easily

to a growing interest in quantifying the effects of energy efficiency on system peak demand. Unfortunately, in contrast to energy (kWh) savings impacts (where there are over two decades worth of extensive and widely published evaluation results), there is a relative scarcity of information about the demand (kW) impacts of energy efficiency. It is not that program evaluations haven't estimated such peak demand impacts, but rather that such estimations have been mostly derived from estimation of energy savings impacts, not measured and estimated directly. This is both a technical issue (kW impacts, especially peak demand impacts, are much more difficult to measure, often requiring additional metering and associated costs) and an artifact of the historic lack of research in this area.

Purpose of this Project and Report

This report examines the relationship between energy efficiency programs and peak demand savings. It presents the major findings of a research project initiated by ACEEE early in 2006. A key objective of the project is to provide a practical information resource for policymakers, program planners, and the public. This resource is intended to provide a basis for discussion and a rationale for energy efficiency as a utility system resource that can both achieve peak demand reduction impacts and save energy and associated costs for customers and utilities. One primary objective of this project was to review existing research, program evaluations, and related literature on the relationship between energy efficiency and peak demand reduction. Another key objective was to review industry practices for estimating demand impacts from energy efficiency programs. This review included identifying and summarizing example programs and related experiences as case studies that demonstrate how energy efficiency programs have achieved significant peak demand savings reductions.

A final key objective was to review existing datasets and technical references on the peak demand impacts of selected energy efficiency measures to provide a ready reference. We compiled data for a set of common end-use energy efficiency measures promoted through utility and other energy efficiency programs, and present these data in Appendix F (available at www.aceee.org/pubs/u073.pdf). This comparative database of selected common energy efficiency measures documents the data available and applied to estimate peak demand impacts from energy efficiency measures and programs. It illustrates how energy efficiency resources are quantified in order to be used within system planning, operations, and market transactions. Such measure-by-measure quantification is the fundamental building block for aggregating multiple energy efficiency measures into resources of sufficient magnitude to be incorporated into utility resource portfolios along with supply resources. This aspect of the project—review of data sets and technical references, along with the analysis and discuss of the issues raised from the review—should be of particular interest to program designers, implementers, and evaluators.

be equipped with a six-ton (6 kW) system. This situation creates an artificially high peak reduction opportunity. In a population of, say, 100,000 air-conditioned homes, this could create up to 300 MW of excess peak demand. And unless all of these homes participated in a demand-response program, the utility would not be able to capture 100% of the demand-response opportunity, forcing the addition of high-cost peaking capacity to the system. Designing these homes efficiently would avoid the need for 300 MW of demand response program costs as well as the added peak generation capacity.

There has been a marked increase over the past few years in efforts to rely on energy efficiency as a utility system resource in meeting customer energy demands and keeping system costs down. This is the essence of "integrated resource planning," which as noted earlier rose to relatively widespread practice in the 1980s and early '90s, but fell away in many states and regions as the wave of restructuring swept across the U.S. Today we see a return to "integrated resource planning," if not in name, at least in concept and practice in many states and regions, including (but not limited to) the Pacific Northwest, California, Texas, Nevada, Minnesota, Iowa, New England, New York, and New Jersey. As utilities increase their reliance on energy efficiency as a viable resource, there is a corresponding need to draw upon accurate data on the energy and demand impacts associated with these resources. This report explores past experience and current practice with the data and approaches used to quantify such impacts for utility system planning and operations.

Overview and Framework of the Report

In the next section (Section 2) of this report, we review and discuss experience with delivering peak demand savings from over 20 years of experience with utility-sector energy efficiency programs. This experience is important to understanding the role and capability of energy efficiency to yield peak demand savings, especially as there are numerous signs today that such demand-side resources will play a larger and larger role within utility and operating system resource portfolios. The objective of Section 2 is to demonstrate the very real contributions that energy efficiency programs have provided in helping address peak demands.

In Section 3, we review and examine common approaches and practices for measuring and quantifying peak demand impacts of energy efficiency. We look to the field and professional practice of program evaluation for the protocols they have established and applied in evaluating energy programs to estimate demand impacts.

Section 4 is an examination and analysis of the published record of energy efficiency program evaluation. Because of a variety of difficulties in accessing and reviewing the body of evaluation research, we turned to two long-running series of conferences that are focused on energy efficiency technologies, programs, and evaluation as proxies for such research. We reviewed the published proceedings of these conferences to assess the number of papers that addressed the measurement and quantification of peak demand savings of energy efficiency programs. This section looks at the practical application of the types of protocols and approaches we examine in Section 3.

In Section 5, we look at the databases and technical references that are used to estimate energy and peak demand impacts of energy efficiency measures. Such references embody the state of knowledge and experience with demand and energy savings from energy efficiency measures. Evaluation and research on customer end-uses of energy—including the type of load research conducted routinely for use in utility forecasting, and system planning and operation—are the primary data sources for the databases we review. In this section we describe Appendix F (available at www.aceee.org/pubs/u073.pdf), a comparative database of selected energy efficiency measures that we developed for this project to illustrate the types of data available for measures commonly offered in energy efficiency programs. We also discuss our experience working with selected databases to compile data from them for a small set of common energy efficiency measures, as well as present summary data from our review.

We present our overall conclusions and recommendations in Section 6.

In this report we include five appendices (four are included as part of this text; the fifth is available as a separate document (available at www.aceee.org/pubs/u073.pdf) to provide more detailed information on a number of the topics we cover in the body of the main report. In Appendix A, we provide definitions and terminology related to energy efficiency and peak demand savings. This appendix is designed to provide a reference for key terms used throughout this report.

Appendix B provides a more in-depth examination of the industry protocols that have been developed for estimating demand impacts of energy efficiency programs. There has been a lot of effort both nationally and internationally to develop such common protocols as a means to assure consistency, quality, and accuracy in the estimation of energy and demand impacts resulting from energy efficiency programs. These protocols lay the foundation for best evaluation practices used by programs across the United States and internationally.

We narrow our focus of evaluation protocols and practices in Appendix C—looking at how these apply not to the industry as a whole, but to individual states. In Appendix C, we examine how selected states approach the evaluation of energy efficiency programs in terms of estimating their energy and demand savings impacts. Most of the leading states have based their specific evaluation and reporting requirements on the protocols for best evaluation practices that we present in Appendix B. These state examples show the practical application of such protocols to suit individual state energy efficiency program needs and resources.

In Appendix D, we further narrow our focus, this time looking at specific program examples that illustrate how evaluators have estimated peak demand impacts. These program examples also illustrate the magnitude of peak demand impacts that have been achieved, measured, and reported by leading programs. We selected examples to represent a variety of both customer classes and end-use technologies addressed by energy efficiency programs.

Appendix E gives contact information for the databases selected for our review.

Appendix F is a comparative database of selected energy efficiency measures. This appendix is a spreadsheet that presents data compiled from a set of five state or regional energy efficiency measure databases that we selected to include in this review and analysis. We also include data from some additional technical references to supplement the state and regional data summaries. This appendix is available at www.aceee.org/pubs/u073.pdf.[3]

[3] To download a free copy a copy of this appendix, go to: http://aceee.org...........][to add address],

2. DELIVERING PEAK DEMAND SAVINGS: PROGRAM RESULTS AND EXPERIENCES

After more than two decades of experience in the utility industry, there is ample experience and evidence to document the fact that energy efficiency programs do provide real peak demand savings. The most striking example occurred during California's electricity crisis of 2000–2001. An unprecedented state-wide effort at reducing peak demands through customer conservation and energy efficiency initiatives yielded unprecedented results. It is most impressive to note that the combined impact of all efforts in California (programs, rate design, public appeals, etc.) in 2001 was a 10% cut in peak demand—about 5,000 MW—and a 6.7% reduction in total electricity use, after taking into account economic growth and weather. Energy efficiency and conservation literally helped "keep the lights on" during this crisis, not to mention ending the price spikes that threatened to damage the state economy.

The table below summarizes estimated demand savings impacts from a set of programs selected and profiled by Kushler, Vine, and York (2002) in examining "reliability-focused energy efficiency programs"—programs that expressly targeted peak demand savings in addition to kilowatt-hour savings because of the capacity shortages and associated reliability problems experienced in many areas of the U.S. in 2000 and 2001.

Table 1. Estimated 2001 Costs and Impacts from a Selected Set of Energy Efficiency- and Conservation-Related Programs

	Program Spending ($million)	Estimated Savings (MW)	Cost per kilowatt*
California	971	3,668	$265/kW
Northwest	150	390	$384/kW
New York	72	263	$274/kW

* These figures are derived by ACEEE using the reported program spending and savings above, and are for simple illustrative purposes only. They represent the maximum cost if the entire program costs were allocated to kW demand savings. In reality, a considerable portion of the benefits from energy efficiency programs are due to energy (kWh) savings. If the program costs were allocated in proportion to the types of benefits obtained, the actual net cost of achieving those kW demand savings would be considerably less.

While the above estimated MW savings impacts were mostly based on engineering analyses, these values indicate the very significant contributions energy efficiency programs are expected to provide to utility energy resource portfolios. An example of a specific program profiled by Kushler, Vine, and York (2002) is the "Keep Cool, New York" program offered by the New York State Energy Research and Development Authority (NYSERDA), which provided rebates to customers who purchased energy-efficient room air conditioners *and* turned in their old, inefficient units for recycling and disposal. This targeted program alone yielded over 11 MW of peak load reduction in the New York City area in one cooling season (2001) from upgraded room air conditioners units (and 15–25 MW in total, counting some miscellaneous additional measures).

California's and other states' experiences during crisis situations provide dramatic examples of the viability of energy efficiency and other conservation efforts to avoid rather dire consequences—power outages. However, California and numerous other states and regions have been quietly reaping the benefits of energy efficiency in helping reduce power demand for ten to twenty years or more during non-crisis conditions.

For this project, we identified recent examples of energy efficiency programs that also demonstrate and document significant peak demand savings. A key criterion for selecting these examples is that the programs used some kind of ex-post measurement of peak demand impacts to estimate overall program impacts. In Appendix D, we provide case studies of the programs demonstrating the viability of energy efficiency to deliver both energy (kWh) and peak demand (kW) savings. Table 2 below presents the summary impacts reported for these selected case studies.

Table 2. Energy and Peak Demand Savings of Selected Programs

State	Program Name	Annual Energy Savings (MWh)	Peak Demand Savings (MW)	MW/GWh*
CA	San Francisco Peak Energy Program	56,768	9.1	0.16
CA	Northern California Power Agency SB5x Programs	37,300	15.9	0.44
CA	California Appliance Early Retirement and Recycling Program	—	—	—
TX	Air Conditioner Installer and Information Program	20,421	15.7	0.77
FL	High Efficiency Air Conditioner Replacement (residential load research project)	—	—	—
CA	Comprehensive Hard-to-Reach Mobile Home Energy Saving Local Program	7,681	3.7	0.48
MA	NSTAR Small Commercial/ Industrial Retrofit Program	27,134	6.0	0.22
MA	2003 Small Business Lighting Retrofit Programs	35,775	9.7	0.27
MA	National Grid 2003 Custom HVAC Installations	980	0.17	0.17
NY	New York Energy $mart^SM Peak Load Reduction Program	—	15.0	—
MA	National Grid 2004 Compressed Air Prescriptive Rebate Program	673	0.098	0.15
MA	National Grid 2003 Energy Initiative Program—Lighting Fixture Impacts	36,007	6.5	0.18
MA	National Grid 2004 Energy Initiative and Design 2000plus: Custom Lighting Impact Study	1,593	0.266	0.17

* This column is derived values from reported peak demand savings and annual energy savings.

These case studies clearly illustrate that energy efficiency programs can yield measurable, significant peak demand savings. Table 1 also illustrates the variability among programs in terms of the relationship between the amount of peak demand savings achieved compared to energy savings. The derived value, "MW/GWh," shows that across this small set of programs, this relationship varies by a factor of about 5. This just mirrors the different relationships that exist between peak demand savings and energy savings of different end-use measures. The case studies also demonstrate the evaluation approaches and techniques necessary to measure and quantify these peak demand impacts.

The success of energy efficiency programs providing measurable and significant resource benefits is leading some states and regions to "raise the bar" in terms of the role of energy efficiency in resource planning and acquisition. The Northwest offers a prime example. The Northwest Power and Conservation Council estimated that energy efficiency programs and related investments since such efforts were begun in 1978 in the region have yielded a cumulative impact of about 3,000 average megawatts[4] of energy savings in 2004. According to its latest long-range, integrated resource plan, the region plans to meet all demand growth through the year 2012 through energy efficiency (NPCC 2005). The near-term target for additional energy efficiency savings is 700 average megawatts by 2009.

The state of New York provides another example of a long-term and ongoing record of using energy efficiency as a utility system resource. NYSERDA estimated that between 1990 and 2001, the state's major energy efficiency programs saved achieved cumulative annual energy savings of 7,095 GWh and reduced summer peak demand by nearly 1,700 MW (NYSERDA 2002), which yields an aggregate program total of 0.24 MW/GWh,[5] using the derived metric described above.

An emerging application of energy efficiency is to target specific geographic areas (rather than utility- or statewide areas) for relieving load on constrained T&D systems. Kushler, Vine, and York (2005) described two recent examples of targeted energy efficiency programs. ISO-New England (ISO-NE) needed an emergency supplemental capacity in 54 targeted communities in southwest Connecticut to avoid potential disruptions in service resulting from the constraints on supplying power to this area. After soliciting bids to provide "demand response" to meet this need, ISO-NE awarded one contract to deliver 4 MW of demand reduction through projects utilizing a variety of energy-efficient lighting technologies (other demand response projects typically reduce load by other means, such as load curtailments associated with lowering lighting or cooling levels). Long Island Power Authority (LIPA) provides another example. In 2004, LIPA announced a comprehensive portfolio of new energy resources that will add over 1,000 MW of new energy to LIPA's portfolio over the next eight to ten years—a portfolio that included energy efficiency and demand reduction. The LIPA plan aims to achieve up to 73 MW of energy and capacity savings. One contractor alone will provide almost 24% of the reductions (17.5 MW) through retrofitting buildings with energy-efficient lighting, heating and ventilation systems, appliances, and refrigeration systems.

[4] "Average megawatt" is a unit of energy used as a convention in the Northwest region, largely because of the hydropower dominance for power generation. An average megawatt is equal to the energy produced by one megawatt over one entire year (8,760 hours), or 8,760 megawatt-hours.
[5] NYSERDA (2002) estimated that the total cumulative energy savings over this period was 57,256 GWh.

3. APPROACHES TO MEASURING AND QUANTIFYING PEAK DEMAND IMPACTS OF ENERGY EFFICIENCY

Quantification of the energy and demand impacts of energy efficiency and other DSM programs is central to relying on these impacts as viable resources within utility resource portfolios and energy markets. Unlike electrical generation and bulk power transfers, there is no simple way to measure the resource contributions of all the individual customer actions taken as a result of energy efficiency programs that in aggregate comprise a system-wide resource. Instead, energy program evaluation employs a variety of tools and approaches to measure and quantify such impacts. The science and practice of energy program evaluation has developed hand-in-hand with the programs themselves. Program evaluators have long recognized the importance of rigorous, sound application of various engineering and statistical methods to yield accurate, credible estimates of program impacts—especially in terms of energy (kWh) and demand (kW) savings attributable to program effects. As a result, energy program evaluation professionals and key stakeholders have developed industry protocols for approaches, specific techniques, and standards of professional practice for quantifying energy program impacts.

Two leading examples of energy program evaluation protocols are:

- *The International Performance Measurement & Verification Protocol* (IPMVP Committee 2002), International Performance Measurement & Verification Protocol Committee.[6] "The International Performance Measurement and Verification Protocol (MVP) provides an overview of current best practice techniques available for verifying results of energy efficiency, water efficiency, and renewable energy projects (page 1)."
- *Evaluators' Protocols, California Public Utilities Commission.* The commission recently directed the development of a comprehensive set of protocols for the "technical, methodological and reporting requirements for evaluation professionals." These protocols represent industry best practices for the measurement and reporting of energy efficiency program impacts (CPUC 2006a). A companion document, which preceded preparation and publication of the *Evaluators' Protocols* is the *California Evaluation Framework* (TekMarket Works Framework Team 2004). Together these volumes present a detailed and comprehensive reference guide for evaluation professionals, program managers, and others involved in program evaluation.

Estimating the energy savings impacts (kWh) of energy efficiency measures and programs typically takes one of two approaches:

- Billing analysis: Use of customer billing (metering) data to estimate program impacts by comparing average energy use from pre-installation data to post-installation data. A common method within this category is the use of "normalized annual consumption" (NAC).

[6] This committee led to the formation of the "Efficiency Valuation Organization," which is a nonprofit organization "dedicated to creating measurement and verification (M&V) tools to allow efficiency to flourish" (see http://www.evo-world.org/).

- Engineering analysis: Use of basic physical laws and equations to calculate energy and demand impacts. Input data to engineering models may include manufacturers' specifications, field testing, and other research.

Appendix B provides details on the protocols and how they are applied to energy program evaluation. Estimating the demand impacts (kW) from energy efficiency and other programs often builds on the estimates of energy savings impacts for a number of reasons. Some of the principal reasons are the availability and costs of data. Energy use data (kWh) are readily available from customer billing data on electricity consumption, which is recorded and tracked by kilowatt-hour meters for virtually all types of customers, from small residential to large industrial or institutional. Demand metering or time-of-use metering is—and has been—common for large commercial and industrial customers. However, utility metering of customer power demand or time-of-use is not routine, particularly for residential and small commercial/industrial customers.

Load Research and Use of Load Shapes and Factors for Estimating Demand Impacts

While customer billing data is clearly a primary source of data for estimating energy and demand impacts from energy efficiency programs, the picture of utility metering and billing practices is gradually changing. There are clearly major changes underway with utility billing practices for all customer classes, including smaller customers, with the development and application of modern communications, metering, data storage, and control technologies. There is great interest in expanded use of time-of-use metering, especially in conjunction with emerging time-differentiated pricing schedules.

While these changing metering and billing practices will provide new data sources that energy program evaluators can use to estimate program impacts, primary data collection for the demand impacts of energy efficiency measures and programs today still generally requires a large amount of time and resources. It typically requires procurement and installation of specific metering equipment beyond that needed by utilities for routine customer metering and billing purposes. This is especially true for residential and small commercial/industrial customers. When demand meters or time-of-use meters are in place at a facility or customer site, program evaluators can often use data from this metering equipment to estimate demand impacts from energy efficiency measures installed as a result of programs. However, even in these cases, it may be difficult to isolate the impacts from a specific measure or set of measures that constitute only a fraction of an entire facility or site—the level at which metering of the customer typically occurs.

Because of these requirements, estimation of demand impacts of energy efficiency programs generally is done by applying load shapes or load factors to estimated energy savings. Customer load shapes and load factors have long been used by utilities for modeling and estimating system demands, both for near real-time system operating requirements and for medium to long-term forecasting. Consequently, utilities over the years have developed and relied upon sets of fairly detailed and sophisticated customer load shapes and load profiles (for example, EPRI 1988). As the practice of DSM emerged, such load shapes have been applied to estimate demand impacts from energy efficiency programs. Such load shapes obviously represent an "average" customer, however that is defined—typically by a set of key characteristics, such as customer class (residential, small commercial, large commercial, industrial) and other distinguishing features of a particular type of customers, such as residential single-family, small retail business, educational facility, food-processing industry, etc.

Accurate load shapes are critical for utilities and electric system operators to be able to forecast system demands and have sufficient resources to meet such demands. This is especially true as reserve margins in most of the United States are relatively low, meaning system demands are stretching existing resources—both generation and transmission—to available capacity. There is little "excess" margin in the system. In fact, the North American Electric Reliability Council recently concluded that the reliability of the electricity supply system in the U.S. will decline unless changes are made soon to boost available resources commensurate with the increasing demands on the system (NERC 2006). Certain regions are especially prone to reliability problems because of this growing disparity between system demand and available system resources, including the Northeast, the Southwest, and the West.

California provides a recent example of the research necessary to estimate customer load curves. The California Energy Commission oversaw a comprehensive study of commercial energy use—"[P]rimarily designed to support the state's demand forecasting activities." (CEC 2006). This research examined energy use among a stratified sample of 2,800 commercial facilities throughout the state. The sample was stratified according to key distinguishing characteristics of commercial customers, including utility service area, climate region, building type, and energy consumption level. The result of the research yielded the following key data for "twelve common commercial building type categories:"

- floor stocks (building sizes)
- fuel shares
- electric consumption
- natural gas consumption
- energy-use indices (EUIs)
- energy intensities
- 16-day hourly end-use load profiles

These types of energy use typically form the "baselines" for estimating any changes in energy and demand that result from customer energy efficiency programs.

California is undertaking other research on customer energy use in order to improve the quality of data available to use for estimating energy efficiency program impacts and related applications. In June 2006, the CPUC directed the utilities to develop a "Load Shape Update Initiative" in an energy efficiency rulemaking (R.06-04-010). The utilities completed this study in November 2006 (CPUC 2006b). The genesis for this project was the need identified by the CPUC to develop more detailed and accurate estimates of load shapes to go along with recently completed more detailed estimates of avoided costs—estimates based on each individual hour within a year rather than a single annual average value as had been used within the database and models in use for program evaluation in California. The project team developed a set of recommendations to improve approaches to developing load shapes for end-use measures and identified key areas of research needed to obtain data necessary to develop more detailed and accurate load shapes for measures included in utility and other energy efficiency programs. We believe these recommendations are a useful start for advancing the evaluation of demand impacts from energy efficiency and other DSM programs. [7]

These examples from California illustrate the types of existing research used for program evaluation along with identified needs to perform additional research to develop more comprehensive and detailed load data, which is needed to be able to quantify and estimate the energy and demand impacts from energy efficiency and other DSM programs. The California Evaluator's Protocols mentioned earlier provide the framework for how evaluations are to be performed; these research efforts provide vital customer demand data to be able to complete accurate estimates of program impacts.

Other states have established evaluation protocols and created technical references and databases to be used for estimating impacts of energy efficiency programs. In Appendix C, we provide summaries of such protocols and practices used in a set of selected states.

In this section we have examined the approaches and practices followed to estimate peak demand impacts of energy efficiency programs. In the next section we examine evaluation and program literature to assess the extent to which these evaluations have used some degree of metered demand savings for one or more of the measures in the study rather than relying on application of load factors or load shapes from secondary industry sources.

[7] An emerging analytical framework worthy of note is the notion of "time-dependent valuation" (TDV), which assesses potential measures by weighting the relative value of reducing electricity use at each different hour of the year.

4. EXAMINING AVAILABLE EVALUATION INFORMATION

Trends in Evaluation Priorities and Focus

The electric utility industry has gone through some dramatic changes as a number of states restructured their markets to allow competition among electricity suppliers at the retail level. Numerous changes also have occurred within wholesale power markets to introduce and allow greater competition. Along with these market changes have come changes in the ways that many customer energy efficiency programs are administered and implemented. In some cases, utilities have continued to perform DSM under "traditional" utility regulation. In other cases, utilities continue to provide energy efficiency and related customer energy management programs, but via different funding mechanisms (e.g., "public benefits" or "public goods" charges rather than as part of periodic rate cases). In still others, non-utility parties administer and provide such programs.

The corresponding needs and uses of energy efficiency program evaluations have changed along with the changes that have occurred in the programs themselves. Program evaluation is a practice that has mirrored many of the changes within the electric utility industry. During the "era of integrated resource planning" (the late '80s into the'90s), program evaluations were viewed as playing a critical role in demand-side management. Evaluation results provided the feedback and quantification of results required by regulators, utility administrators, and program managers. Given this critical role, funding for program evaluation was relatively high, with hundreds of millions of dollars spent nationally on program evaluation during that period.

As "deregulation" and "industry restructuring" took hold in many states beginning in the mid-'90s, funding for energy efficiency and related customer energy programs fell dramatically (York and Kushler 2005b). And with this large decrease, budgets for program evaluations plummeted as well. Moreover, as the types of programs and their objectives shifted, there was less focus on assessing the energy and demand impacts of programs. Greater emphasis was placed on estimating market indicators, including "market share" or "market penetration." Linking specific customer changes in energy use resulting from program services became less of a priority than measuring movement of entire markets for products and services. The regulatory changes that occurred in many states also meant that these bodies no longer had responsibility for long-term energy planning—or at least not to the degree they had under "integrated resource planning." These changes had significant impacts on the types and extent of energy efficiency program evaluation. The use of metered data from individual customer sites decreased dramatically as evaluation priorities and resources changed.

More recently, interest in being able to estimate and document the energy and demand impacts of energy efficiency has grown considerably. Concerns about electric system reliability and the desire to use energy efficiency as a true electric system resource have led to the need to be able to measure and rely upon actual program impacts on system load.

Review of Published Evaluation Results

It is difficult to access and review the body of evaluation research available in this field. Many such reports are not publicly available, particularly as the industry has become more competitive and more information and data are proprietary. There is no over-arching program evaluation industry "index" that reports on evaluation activity or results.

As a proxy for such a data set, however, we turned to two key sources within the energy efficiency program industry. These are biennial conferences where program practitioners—planners, managers, consultants, implementers, evaluators, researchers, and others—present and publish papers relative to their work with energy efficiency programs, technologies, and policies. These conferences are:

- ACEEE biennial Summer Study on Energy Efficiency in Buildings, and
- International Energy Program Evaluation Conference.

We reviewed the published conference proceedings for the International Energy Program Evaluation Conference (IEPEC 1993–2005) and the ACEEE Summer Study on Energy Efficiency in Buildings (ACEEE 1994–2006) for evaluations of energy efficiency measures and programs that demonstrated demand impacts.

Specifically, when the conference proceedings were available on CD-Rom, we electronically searched the proceedings for keywords like "kW," "MW," "demand savings," etc. In years for which we only had a paper copy of the proceedings, we visually scanned each paper for demand savings. Since the primary objective was to identify energy efficiency measures or programs with demand savings, we eliminated evaluations of load management and demand response programs, as well as efficiency standards and/or building codes. In addition, we only considered energy efficiency papers with specific demand savings figures.

We then categorized the evaluations by sector (residential, commercial/industrial, and agricultural), whether the study provided demand savings by measure or program, and whether the study included some level of metered demand savings for one or more of the measures in the study.

Tables 3, 4, and 5 summarize our findings. We found that only 2.9% (78/2,664) of the conference papers that we reviewed presented energy efficiency measures or programs with numerical demand energy savings. A little more than half (45/78) of those evaluations involved some type of actual metering as part of the methodology. A slightly higher percentage (3.3% vs. 0.9%) of conference papers in the earlier years (1993–1997) included actual metered demand savings compared to studies from conferences in the later years (1998–2006).

One of the most important findings in this review was the small number of energy efficiency studies that documented demand impacts in the fourteen years of conference proceedings. Whereas energy savings (kWh) were commonly provided in the energy efficiency evaluations, demand savings were established much less often. Another related key finding is the change in these numbers over time. In the early '90s we found a relatively large number of papers directly on this topic—but as the '90s proceeded, we found fewer and fewer such papers. Published papers in this latter period tended to rely on applying load curves (developed in the '80s and early '90s) to the estimated energy (kWh) impacts, rather than using metered demand data specific to the program being evaluated.

These findings reflect evaluation priorities, and technical and cost issues associated with estimating peak demand impacts. Historically the emphasis for evaluation of energy efficiency programs has been to estimate energy (kWh) savings since such savings are the primary program objective. Estimating peak demand impacts typically has not been a high priority. As shown in our review and analysis of conference proceedings, many evaluations simply did not estimate or report peak demand impacts. This by no means suggests any kind of shortcoming of the evaluators or program managers; it simply reflects the needs and objectives of program administrators and evaluators working within budget and resource constraints.

Other factors that explain the relative lack of research and evaluation on peak demand impacts of energy efficiency programs are technical and cost issues, which clearly also influence prioritization and evaluation resource allocation. Peak demand impacts are typically much more difficult to measure and estimate accurately than energy (kWh) savings impacts, generally requiring additional, dedicated metering (time-of-use or other demand metering, monitoring, and logging hardware) and associated costs. It is no surprise that when faced with limited—and even diminishing—evaluation budgets over the period examined in this analysis, evaluation budgets and resources have focused on accurate estimation of the impacts (kWh savings) determined to be most important by regulators and program administrators for these types of programs.

With the renewed interest and use of energy efficiency as a resource, the importance of estimating both energy and demand impacts accurately is increasing. Emerging market structures and transactions that allow demand resources to participate in energy markets similarly will increase the importance of accurate estimation of these resources. For example, there is work underway to include energy efficiency resources within the ISO New England Forward Capacity Market (Peterson et al. 2006). With this growing importance of accurate quantification of the energy and demand impacts of energy efficiency programs, we expect to see renewed and expanded evaluation efforts that will explicitly include metered demand impacts as part of the program evaluations.

The expanding use of more advanced customer metering technology will also facilitate the use of demand data in program evaluations. New and expanded use of advanced metering technologies also may help address cost issues associated with estimation of peak demand impacts. As utilities increase the number of customers with time-of-use meters in place for routine billing purposes (clearly in conjunction with time-of-use rate structures), program evaluators will be able to use this time-differentiated usage data without the need to install separate, dedicated metering and logging equipment. This alone will greatly reduce costs associated with estimating peak demand impacts. Advances in metering technology also have greatly reduced the costs associated with many monitoring and evaluation practices. The advent and advancement of numerous "smart" technologies, such as those used in building systems, along with advances in communication technologies have created new opportunities to gather data at relatively low costs. Most data-gathering functions can be performed remotely, especially if such capabilities are integrated with the monitoring and control functions of end-use equipment and systems.

There well may be an advantageous convergence of need, capabilities, and costs emerging for estimating peak demand impacts. As utilities and system operators rely more and more on demand-side options to address peak demand and related reliability concerns, their needs for accurate and timely quantification of demand-side impacts increases commensurately. Parallel with these trends are rapid increases in the capabilities of monitoring and communications technologies that can yield relatively low costs for data gathering and analysis. It was beyond the scope of this project to explore more specific costs and possible benefits of these new evaluation opportunities relative to past and present practices. It will be important for utilities and regulators to work with the program evaluation community to address these issues and weigh the many factors that go into developing evaluation plans, including program objectives, evaluation priorities, budgets, costs, capabilities, and needs.

Table 3. Energy Efficiency Studies that Used Some Level of Metering for Demand Savings Estimates

Residential Measures/Program	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
New construction—daylighting, HVAC, etc. (measures)	1		2										
HVAC (measures)	1											1	
Ground-source heat pump (measure)				1		1							
Lighting (program)		1			1								
Exterior wall insulation (measure)				1									
Mobile home—AC tune-up, duct sealing (measures)												1	
Energy-efficient showerhead (measure)	1												
Total metered residential studies	3	1	2	2	1	1	0	0	0	0	0	2	0
Commercial/Industrial Measures/Program	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Lighting, photocontrols, daylighting sys. (measures)		1	3			1		1					
Lighting, photocontrols, daylighting sys. (program)	1			1	2						2		
Multiple—process, lighting, motors, HVAC (program)	1		1	1									1
New construction—daylighting, HVAC, etc. (measures)	1		1			1							
Historical overview, multiple measures (program)	1							1					1
HVAC (measure)					2								
New construction—daylighting, HVAC, etc. (program)					1								
Multiple—process, lighting, motors, HVAC (measures)				1									
VSDs (measure)		1											
Refrigeration (measure)										1			
Energy management systems (program)				1									
Vending machines (measure)													
Irrigation pump repair (measure)							1						
Total metered C&I studies	4	2	5	4	5	2	1	2	0	1	2	0	2
Total metered energy efficiency studies	7	3	7	6	6	3	1	2	0	1	2	2	2
Total conference papers reviewed	139	292	121	247	83	258	96	309	71	273	103	274	115
% of papers that used some level of metering	5.0%	1.0%	5.8%	2.4%	7.2%	1.2%	1.0%	0.6%	0.0%	0.4%	1.9%	0.7%	1.7%
Percentage of metered studies 1993–1997							3.3%						
Percentage of metered studies 1998–2006							0.9%						

Table 4. Studies that Did Not Use Metering for Demand Savings Estimates (Used Models, Engineering Estimates, etc.)

Residential Measures/Program	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Low-income weatherization, lighting, etc. (program)	1										2		
HVAC (program)							1						
Refrigerator recycling (measure)										1	1		
Vegetative cooling (program)		1					1						
Vegetative cooling (measure)								1					
HVAC (measure)												1	
Ceiling insulation (measure)		1											
Energy efficient windows (measure)				1									
Multiple—lighting, HVAC (measures)													1
Total non-metered residential studies	1	2	0	1	0	0	2	1	0	1	3	1	1
Commercial/Industrial Measures/Program	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Lighting, photocontrols, daylighting sys. (measures)	1		1	1		1		1					
Multiple—process, lighting, motors, HVAC (program)	1												1
HVAC (measure)			1	1									
HVAC (program)				2									
New construction—daylighting, HVAC, etc. (program)									1				
New construction—daylighting, HVAC, etc. (measures)												1	
VSDs (measure)			1										
Ground-source heat pump (measure)						1							
Snowmaking machinery (measure)	1												
School program—full-time energy manager (program)			1										
Multiple—process, lighting, motors, HVAC (measures)								1					
Total non-metered C&I studies	3	0	4	4	0	2	0	2	1	0	0	1	1
Total non-metered energy efficiency studies	4	2	4	5	0	2	2	3	1	1	3	2	2
Total conference papers reviewed	139	292	121	247	83	258	96	309	71	273	103	274	115
Percentage of papers that did not use metering	2.9%	0.7%	3.3%	2.0%	0.0%	0.8%	2.1%	1.0%	1.4%	0.4%	2.9%	0.7%	1.7%
Percentage of non-metered studies 1993–1997	1.7%												
Percentage of non-metered studies 1998–2006	1.0%												

Table 5. Summary of Energy Efficiency Studies with Demand Savings Estimates

Summary Data	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Metered + non-metered studies with demand savings	11	5	11	11	6	5	3	5	1	2	5	4
% of energy efficiency papers with demand savings	7.9%	1.7%	9.1%	4.5%	7.2%	1.9%	3.1%	1.6%	1.4%	0.7%	4.9%	1.5%

5. Comparative Database of Energy and Demand Impacts of Selected Energy Efficiency Measures

Background and Overview

The nature of demand-side resources is that they are widely dispersed among hundreds—even thousands—of individual customers and customer applications. Quantifying this resource requires accounting for all relevant customer applications and associated savings, and then summing them up to arrive at program totals. In turn, all programs within a utility's or other program administrator's portfolio can be summed up to arrive at an aggregate system resource total. To quantify demand-side resources thus requires quantification of the energy and demand savings attributable to each individual customer application, whether as small and simple as a single compact fluorescent light bulb or as large and complex as an industrial process retrofit. To facilitate and streamline this process, program developers, administrators, evaluators, and other stakeholders have developed a variety of technical references and tools to perform this function, particularly for the types of measures that are more uniform from application to application, such as appliance or lighting upgrades. The amount of data required on individual measures varies from program to program, but generally there may be a dozen or even dozens of data fields for any given measure (for example, nameplate specifications, baseline energy use, retrofit energy use, baseline demand, retrofit demand, hours of operation, climate variables, etc.). Some type of database is clearly an effective solution as a way to manage and use such a large amount of data.

There are indeed numerous such databases and technical references that catalog individual energy efficiency measures and include key data relevant to their energy and demand impacts. Such databases are used in a variety of ways. Often they are used to identify and analyze the cost-effectiveness of individual measures. Used in this manner, they may screen general types of measures (for example, high-efficiency residential room air conditioners) as a way to determine their eligibility to be included as customer options within programs. Another use of these databases is to analyze specific measures under consideration by individual customers, particularly applications where customer variables may affect eligibility (for example, such variables might be hours of operation or climate zone). A third use is to aggregate and quantify total program impacts—either prospectively, as used for program design and development, or retrospectively, for assessing actual program results and impacts. Program evaluation may be used to assess the accuracy of the assumptions and data used in databases based on ex post analysis of actual customer applications that result from a given program. Evaluation results thus can be used to update and fine-tune the data in the databases to improve their accuracy.

In this section we describe our selection and review of selected databases. We also describe our selection of measures and compilation of data on these selected measures within these databases. Our intent is to present examples that illustrate the types of measures commonly included in utility-sector program databases. In these examples we also seek to show typical values used for peak demand and energy savings associated with specific measures with data drawn from the databases we selected for inclusion in this review. The amount of data included in any of the typical databases we reviewed is immense—for example, the database in use in California has over 130,000 records (measures) included. In no manner did we seek to create some sort of annotated or summary database that could be used as a stand-alone replacement for any of the comprehensive databases that we reviewed. Rather, our comparative database should be viewed as selected detail from a much larger picture. The data we compiled and report are really starting points for program design, implementation, and evaluation. The data could readily be used at the program scoping and development stage for certain types of programs, such as residential refrigerator replacement or window air conditioner programs. Using these data could yield order-of-magnitude estimates of possible resource impacts that could result from implementing a certain type of program. At the more detailed, technical level of program implementation and evaluation, we believe these illustrative data might be a starting point for more in-depth examination and analyses of particular sets of measures and entire programs. Some of the measures and associated data might serve as cross-checks or additional references for program evaluators and implementers to assess program impacts. We include links and contact information for each of the databases we selected for readers interested in more information.

We conclude this section with an analysis and discussion of what we found in going through this process—results, problems, and recommendations.

Identification and Selection of Databases

As discussed earlier, utility-sector energy efficiency programs have evolved over the past 20 or more years. The data and analytical tools used with demand-side management and other energy efficiency programs have similarly changed over the years. We found that states and even regions offering energy efficiency programs (whether administered by utilities or non-utility organizations) have tended to develop such data and analytical tools to meet their specific needs and circumstances. There isn't a "one-size-fits-all" database or technical reference being used by the leading programs we examined for applications anywhere in the country. This makes sense given the great variability in technical dimensions of specific end-use energy efficiency measures for given applications as well as the great variability in the characteristics and associated needs of electricity supply systems and the energy efficiency programs serving those systems.

We conducted a search to identify databases and similar technical references that are used by leading utility-sector energy efficiency programs. One of our selection criteria was to provide diversity in terms of climate as that obviously is a key variable. We also sought diversity in terms of electricity supply system characteristics (e.g., winter/summer peaking, generation and fuel types, transmission capabilities and constraints). We also sought diversity in the size and structure of programs (type of administration and implementation). Beyond these broad characteristics we also sought databases that generally met the following criteria:

- Are publicly available and accessible,
- Include a relatively comprehensive set of end-use measures commonly included in energy efficiency programs,
- Have been in use over several years or more,
- Include data and/or algorithms for both energy (kWh) and demand (kW) savings, along with sufficient detail on other key parameters and specifications, and

- Are well-documented.

Below we identify and describe the databases and technical references we found that met our search criteria.

Database for Energy Efficiency Resources (DEER). California Energy Commission.
"The Database for Energy Efficient Resources is a California Energy Commission and California Public Utilities Commission (CPUC) sponsored database designed to provide well-documented estimates of energy and peak demand savings values, measure costs, and effective useful life (EUL) all with one data source." (CEC and CPUC 2005).

DEER contains over 133,000 records that include demand impact estimates, which are based on engineering calculations, building simulations, measurement studies and survey, economic regressions, or a combinations of approaches.

Deemed Savings Database, Version 9.0. NYSERDA.
"Deemed savings[8] measures are a collection of pre-approved measures for which NYSERDA has calculated stipulated savings values. These measures are used across multiple New York Energy $mart programs." (NYSERDA 2006).

Deemed Savings, Installation & Efficiency Standards: Residential and Small Commercial Standard Offer Program, and Hard-to-Reach Standard Offer Program. Public Utility Commission of Texas.
The *Deemed Savings, Installation & Efficiency Standards* is a set of approved energy and peak demand deemed savings values established for energy efficiency programs in Texas (PUCT 2003). These values were developed through a collaborative process overseen by the Public Utility Commission of Texas, which approved the final values.

Conservation Resource Comments Database. Northwest Power and Conservation Council.
The *Conservation Resource and Comments Database* (NPCC 2007) was created by the Regional Technical Forum (RTF), which is a collaborative of key stakeholders associated with the Bonneville Power Administration (BPA) and regional energy planning in the Pacific Northwest (the states of Washington, Oregon, Idaho, and western Montana). The Northwest Power and Conservation Council leads, coordinates, and administers the RTF, and in turn, the database, which includes costs, savings (kWh and kW), and related measure data used to determine costs and benefits. It also includes online submission forms for comments, both for measures already included in the database and for any measures that interested stakeholders wish to be considered for future inclusion.

Technical Reference User Manual (TRM). Efficiency Vermont:
TRM is a catalog of measure savings, algorithms, and cost assumptions used by Efficiency Vermont (2003). Data include estimated electricity (kWh) and demand (savings), along with costs, load curves, and other data as needed to estimate costs and benefits of the measures.

[8] "Deemed savings" is a term used to describe an estimated savings value for a given measure that is accepted by a group of stakeholders, such as utilities and regulators. Typically such estimates are developed through collaborative processes involving technical review and analysis of the measures.

We also include more limited data from other technical references for selected measures. These are primarily national level sources not serving any particular state or regional program, namely:

- U.S. EPA/DOE ENERGY STAR product specifications (U.S. EPA 2006),
- Consortium for Energy Efficiency (CEE) product specifications (CEE 2006), and
- American Council for an Energy-Efficient Economy "emerging technologies" report and database (Sachs et al. 2004).

We also include a limited amount of data on a limited set of selected commercial/industrial measures from National Grid (Newberger 2006). These supplemental data sources are to provide cross-checks of the primary program data and also references for additional data. The national level data primarily address energy savings impacts; data on demand impacts is limited.

One especially important note about the above databases is that those for California, New York, Texas, and Vermont are for utility systems that are summer peaking. The Regional Technical Forum serves utilities in the Pacific Northwest, which is winter peaking. This difference has obvious implications for the peak demand impacts of certain measures.

For more information on these databases and how they are used by the relevant energy efficiency programs in their states or regions, see Appendix C.

Measure Selection and Objectives for Data Compilation

Our review of existing databases and technical references made it quickly obvious that we could not duplicate the depth and breadth of materials already available within the scope of this project. Such duplication would not be particularly useful, either. Creating such a comprehensive database on the order of those that we found was not the intent of this project. Rather, our objective was to develop a relatively small, comparative database for selected, common end-use efficiency measures. We sought to create a reference tool that contains small sets of measures commonly included in programs within three key sectors—residential, commercial and industrial—and that contains key data from the state and regional program databases we reviewed. The intended purpose of this database is to allow ready comparison of data and illustrate typical demand savings estimated for various measures.

Within each major sector, we selected measures that are commonly offered in programs—those energy efficiency measures that also can have significant peak demand impacts. We also selected measures that represented dominant electric end-uses within each customer sector, such as lighting, air conditioning, and refrigeration. Within most end-uses and measure types there are numerous sub-categories and variations. For example, residential refrigerators may be categorized according to size of the unit (volume) and by physical configuration (for example, top freezer, bottom freezer, or side-by-side freezer). We tried to select measures in these cases that might be fairly common or that otherwise represent more of an "average" application. Continuing the refrigerator example, we tried to select the refrigerator data listing from each database that was in the middle of the size range and that was the most common configuration (a top freezer unit).

Below we list the measures we selected for the comparative database.

Residential:

- ENERGY STAR room air conditioners
- Energy-efficient central air conditioners
- ENERGY STAR refrigerators
- ENERGY STAR freezers
- ENERGY STAR clothes washers
- Compact fluorescent light bulbs
- ENERGY STAR fluorescent torchieres
- Infiltration reduction—single-family housing
- ECM fans (blowers) for home HVAC

Commercial:

- Packaged rooftop HVAC units
- Energy-efficient chillers
- HVAC controls/energy management systems
- Variable speed drives
- Compact fluorescent light bulbs
- Daylight controls—lighting
- Occupancy sensors—lighting
- Premium efficiency motors (5, 10, and 25 hp)
- T-8 fluorescent lamps with electronic ballasts
- Commercial office equipment: high efficiency copiers
- Commercial packaged refrigeration
- Commercial vending machine controls ("Vending Miser")

Industrial:

- Premium efficiency motors (40, 75, 150, and 200 hp)

We also note several end-use energy efficiency measures that we had intended to include, but found insufficient data across the set of our selected databases. These measures are:

- Residential: consumer electronics/media equipment, comprehensive single-family home weatherization.[9]
- Commercial: commercial building retro-commissioning, office equipment—monitors.
- Industrial: compressed air equipment and controls.

[9] "Weatherization" generally is used to describe a package of measures performed on building envelopes to reduce heat loss, including insulation (of ceilings, walls, and foundations) and sealing of air leakage (infiltration reduction).

In the above cases, exclusion from the databases is likely due to one of two reasons: (1) The measures aren't included in any programs: consumer electronics/media equipment clearly falls into this category, or (2) The measures are not amenable to database approaches for deemed or otherwise standardized savings estimates. Commercial building retrocommissioning is a primary example in this category. Estimating energy and demand savings from retrocommissioning accurately requires relatively detailed and project-specific measurement and verification.

Datafields Included

In this project, our focus is the peak demand savings from energy efficiency measures. This focus guided the selection of datafields (or measure variables and specifications) that we included. Since energy savings are so clearly related to demand savings, we also included estimated energy savings. This also provides a bit of a "gauge" as well since many program professionals typically think more in terms of the magnitude of energy savings (in kilowatt-hours) when analyzing energy efficiency measures. Below we list the datafields that we included in compiling our comparative database of selected measures.

The datafields we include are:

- ACEEE measure name
- ACEEE database code
- Name of source database or technical reference
- Link or citation number for the source database or reference
- Measure name or summary description/specification from source database or reference
- Notes/description of measure from source database—key assumptions, inputs
- Energy savings (kilowatt-hours)
- Maximum demand savings or full-load gross demand reduction (kilowatts)
- Summer coincident peak demand savings
- Summer coincident peak savings factor
- Winter coincident peak demand savings
- Winter coincident peak savings factor
- Measure references/sources from source database.

Most of the reference databases from which we gathered data include many more datafields for each measure, representing data and variables important for other aspects of program planning, implementation, and evaluation. We restricted our search and compilation to only the datafields most relevant to our focus on demand savings of energy efficiency measures. Where possible we include any type of "code" or "reference number" used in the various databases and references to allow ready access to the full record for any given measure selected.

Results, Analysis, and Recommendations

An early vision for an outcome of this project was a selected set of uniformly defined measures for which we would be able to compile data to allow ready comparisons among programs for these specific measures. We soon realized that this would prove to be a difficult, even impossible, task within the scope and resources of this project. We found that there simply is not uniformity in how end-use measures are defined and specified except for a relatively small set of the most simple consumer devices, such as compact fluorescent light bulbs. Generally we found that as devices increased in size, complexity, and variety within a general category (residential refrigerators, for example), the different program databases defined the measures differently. While in many cases the definitions might yield similar measures, they still for the most part were not identical. This result really should not be surprising given the variation across the states and regions of the U.S. in any number of influences on consumer products and services, including:

- Consumer preferences and needs
- Local building stock and construction practices
- Codes and standards
- Product distribution channels
- Climate
- Energy costs, prices, and market conditions,
- Energy efficiency program history and experience

Other key variables are the data needs and resources of the energy efficiency programs themselves. These databases all were developed with very specific program needs and objectives in mind. One would not expect a database developed to serve multiple, large integrated electric utilities in a populous state like California, which also encompasses numerous widely varying climate zones (from hot dessert areas to high mountains), to be the same as that developed for use by a single, non-utility organization, such as Efficiency Vermont, serving a relatively small state with a fairly uniform climate. Thus while DEER, used in California, has over 130,000 records with substantial detail and numerous datafields (variables for each), the "Technical Reference User Manual," used in Vermont, is a fairly concise catalog of measures with just over 100 categories of defined measures. Each of these measures, in turn, may give multiple variations possible within each category. The net result is that this manual likely yields a total of possibly several hundred to a thousand or more distinct measures (we did not attempt to estimate this exact value). The volume of data in DEER necessitates the use of an electronic database format. By contrast, the "Technical Reference Manual Exists" as a text document (about 300 pages) with data tables and algorithms. Clearly the use and application of each database varies widely, yet each does contain common datafields since ultimately the energy—and in many cases, demand—impacts are the desired outcomes from using these tools, along with other cost and performance estimates.

These databases generally encompass energy efficiency measures that are single devices (such as lighting fixture, lamps, appliances, motors, and air conditioning units). Some "services" are included in some of the databases, such as "residential weatherization" or more specific services, such as increased roof insulation, infiltration reduction, and duct sealing. Controls and control systems are also sometimes included, such as those for commercial lighting or HVAC systems. In practical terms, this means that measure coverage within databases tends to be heavily weighted to residential and small commercial customers and applications. Energy efficiency improvements for large commercial and industrial customers tend to involve much more complex systems and customized applications of multiple devices. Such improvements defy any kind of standardization that is required to be included in databases. This fact is well recognized and acknowledged by administrators of energy efficiency programs serving these customers. Consequently, programs rely on different means and references to estimate the energy and demand impacts of improvements made in these more complicated systems. As an example, the Texas Public Utility Commission requires program administrators and contractors to follow measurement and evaluation guidelines for standard offer programs that serve larger commercial and industrial customers with a variety of services to improve end-use energy efficiency (see Appendix C).

While many energy efficiency measures for large commercial and industrial customers are not readily handled within standardized databases or technical references, there clearly are some measures amenable to such coverage. These are measures that involve specific devices, such as LED exit lights, high efficiency motors, T-8 lamps, or packaged HVAC units. We include such measures in our comparative database.

There was a category of energy efficiency measures that we intended to include as they offer a significant potential for peak demand. This category comprises the vast and growing world of consumer and commercial electronics—computers, televisions and home entertainment/media systems, printers, copiers, etc. As described and discussed in work that ACEEE has done in the area of "emerging technologies" (Sachs et al. 2004), some new devices within this category can greatly reduce customer energy use and also promise significant demand reductions in certain types of applications, particularly when used in business and work settings when the devices are most used during times of systems peak demands (weekday afternoons for most summer peaking utilities). Despite our desire to include such products in our comparative database, we discovered that few utility-sector programs address or include such measures so the technologies aren't included in the respective databases.

The comparative database of selected energy efficiency measures that we created for this project is available included as Appendix F (available at www.aceee.org/pubs/u073.pdf). In this database (organized as a spreadsheet), we present summary data as best possible for each datafield for each selected measure. These summary data are ranges, median, and mean values. In some cases the selected measure may have only been included in one or two of the program databases; in such cases, we note that finding. Table 6 presents summary data from this database.

As we expected, the measures for which it is possible to have the most uniform definition (for example, residential 15 watt compact fluorescent light bulb replacing a 60 watt incandescent) show the most uniformity in terms of reported energy and demand savings. Other measures that were not as uniformly defined tend to show wider variations. Similarly, measures that are climate sensitive (mostly those associated with air conditioning, such as residential room and central units, commercial packaged HVAC units, and commercial chillers) also tend to show wide variations, as would be expected. Again, these summary values are intended to show the magnitudes of reported energy and peak demand savings from common energy efficiency measures. It was beyond the scope of this project to investigate any apparent discrepancies or errors from individual databases, or otherwise to try to explain wide variations among reported values for similar measures.

Table 6. Summary Table from the Comparative Database of Selected Energy Efficiency Measures

	Coincident Summer[1] Peak Demand Savings				Annual Energy Savings			
	Reported kilowatt (kW) savings				Reported kilowatt-hour (kWh) savings			
	Min	Max	Median	Records	Min	Max	Median	Records
Residential Measures								
ENERGY STAR room air A/C	0.058	0.067	0.063	3	40	181	47	4
Energy-efficient central A/C	0.435	0.864	0.742	4	288	666	378	5
ENERGY STAR refrigerators	0.006	0.011	0.009	4	52	212	61	5
ENERGY STAR freezers	0.005	0.005	0.005	1	39	39	39	1
ENERGY STAR clothes washers	0.009	0.193	0.051	4	298	676	463	5
Compact fluorescent light bulbs	0.004	0.009	0.006	4	39	95	58	5
Fluorescent torchiere	0.020	0.028	0.025	3	180	325	231	4
ECM furnace fan	0.147	0.147	0.147	1	396	396	396	1
Infiltration reduction	Four out of the five references report values for infiltration reduction of single-family homes. However, there is too much variation in how this measure is defined and how the savings are reported (not common units) to provide meaningful comparative data in this summary table.							
Commercial Measures								
Energy–efficient packaged roof-top HVAC units 5–12 tons	0.020 kW/ton	0.232 kW/ton	0.083 kW/ton	4	20 kWh/ton	202 kWh/ton	143 kWh/ton	4
Energy-efficient chillers 150–300 tons centrifugal	0.067 kW/ton	0.102 kWh/ton	0.085 kW/ton	2	99 kWh/ton	205 kWh/ton	152 kWh/ton	2
HVAC controls/energy management systems	Two out of the five references report values for some type of HVAC controls/EMS improvements. However, there is too much variation in how this measure is defined and how the savings are reported (not common units) to provide meaningful comparative data in this summary table.							
Variable speed motor drives	0.071 kW/hp	0.252 kW/hp	0.203 kW/hp	3	822 kWh/hp	1656 kW/hp	1001 kW/hp	3
Compact fluorescent light bulbs	0.006	0.039	0.026	4	37	190	143	4
Daylight controls	Three out of the five references report values for some type of daylighting control. However, there is too much variation in how this measure is defined and how the savings are reported (not common units) to provide meaningful comparative data in this summary table.							

	Coincident Summer[1] Peak Demand Savings				**Annual Energy Savings**			
	Reported kilowatt (kW) savings				**Reported kilowatt-hour (kWh) savings**			
	Min	**Max**	**Median**	**Records**	**Min**	**Max**	**Median**	**Records**
Occupancy sensors	Three out of the five references report values for occupancy sensors for lighting. However, there is too much variation in how this measure is defined and how the savings are reported (not common units) to provide meaningful comparative data in this summary table.							
Premium efficiency motors—5 hp	0.056	0.070	0.063	2	148	329	163	3
Premium efficiency motors—10 hp	0.117	0.148	0.133	2	146	690	311	3
Premium efficiency motors—25 hp	0.151	0.191	0.171	2	547	893	788	3
T-8 fluorescent lamps with electronic ballasts	0.006	0.008	0.008	3	22	49	46	4
Commercial packaged refrigeration	0.112	0.112	0.112	1	1088	1088	1088	1
Commercial vending machine controls (“Vending Miser”)	0	0.114	0.057	2	1022	1635	1406	4
High efficiency copiers	0.041	0.041	0.041	1	324	324	324	1
Industrial Measures								
Premium efficiency motors—40–50 hp	0.219	0.471	0.345	2	1026	1346	1294	3
Premium efficiency motors—75 hp	0.474	0.551	0.513	2	1575	2795	2585	3
Premium efficiency motors—150 hp	0.575	0.728	0.652	2	2080	4032	3394	3
Premium efficiency motors—200 hp	1.146	1.450	1.298	2	3255	6759	5343	3

[1]Data for four of the technical references used are for summer peaking systems (California, New York, Texas, and Vermont). The fifth technical reference is for the Pacific Northwest, which is a winter peaking system. Comparable summer peak demand reduction data are not available; only winter peak demand savings are reported for the Pacific Northwest (NPCC 2007), as well as annual energy savings.

We found that generally the databases provide reasonably good documentation of the data references and key assumptions. This is critical to allow ready checking on the source and accuracy of reported data and to understand key assumptions. It also easily allows updating and comparison to other references.

As we have discussed throughout this report, the relationship between energy savings (kWh) and peak demand savings (kW) can vary widely among different types of measures and programs. This relationship is defined by the load curve associated with a given end-use. Climate variations clearly affect climate-sensitive measures, such as air conditioning of homes and commercial buildings. Even non-climate-sensitive measures can vary widely from application to application. To illustrate the relationship between peak demand and energy savings, Table 7 presents selected estimates of “peak demand reduction savings (measured in Watts) per energy savings (measured in kilowatt-hours).” The figures reported in Table 7 are median values that we derived from reported values of peak demand and energy savings in the databases. They indicate the relative magnitude of this relationship by different types of measures.

Table 7. Peak Demand Savings Expressed per Unit Energy Savings for Selected Measures

Measure	Peak Demand Savings per Energy Savings (W/kWh), Median Values
ENERGY STAR room air A/C	1.59
Energy-efficient central A/C	1.29
ENERGY STAR refrigerators	0.14
Compact fluorescent light bulbs	0.10
Energy-efficient packaged roof-top HVAC units 5–12 tons	0.74
Energy-efficient chillers 150–300 tons centrifugal	0.59
Premium efficiency motors—25 hp	0.26
Premium efficiency motors—200 hp	0.18
T-8 fluorescent lamps with electronic ballasts	0.31

6. FINDINGS AND CONCLUSIONS

Our major findings in this study are:

- Energy efficiency programs clearly have achieved significant peak demand reductions. We found examples of clear, well-documented estimates of such impacts from individual measures, entire programs, and entire state and regional utility systems.
- While we found well-documented estimates of peak demand impacts of energy efficiency, most program evaluations have not used direct, onsite measurement of the demand impacts. Rather, program evaluations typically have relied on customer billing or other measurements of kilowatt-hour use as primary data. Load shapes or load factors are then applied to these data to estimate the peak demand impacts.
- As utilities and system operators increase their use of energy efficiency programs as energy system resources to deliver both energy (kWh) and peak demand (kW) savings, the need for greater understanding and accurate quantification of the peak demand impacts of energy efficiency will increase.
- There are solid foundations in place for establishing a firmer, broader knowledge base of the peak demand impacts of energy efficiency. There are numerous technical references and databases in use that provide measure-by-measure quantification of these impacts and the professional evaluation community has well-established practices and protocols for addressing this growing need.
- There well may be an advantageous convergence of need, capabilities, and costs emerging for estimating peak demand impacts. Rapid increases in the capabilities of metering and communications technologies can yield relatively low costs for data gathering and analysis.

Energy efficiency programs clearly can yield significant peak demand savings. Over twenty years of experience with such programs, documented by load research and program evaluations, verifies such impacts. However, while it's certainly true as a general principle that energy efficiency programs yield real peak demand savings, our review of program experience, evaluation results, and industry protocols and practices shows that there has been a historical lack of emphasis on the direct measurement of those peak demand impacts. Instead, the majority of program evaluations have tended to rely on applying existing data sets and load shapes rather than collecting primary peak demand impact data via metering and other methods. This finding clearly reflects historical program and evaluation priorities: energy (kWh) savings have been the primary objective of energy efficiency programs. Therefore, measuring those impacts has been the focus of program evaluators, and evaluation resources have been allocated accordingly. Cost and technical issues also have influenced the nature of energy efficiency program evaluations. Peak demand impacts are typically much more difficult to measure and estimate accurately due to additional metering and related data gathering equipment requirements, which also add to evaluation costs.

While such evaluation objectives, priorities, and practices are understandable given the history of energy efficiency programs, it is nonetheless likely that better data on peak demand impacts would help strengthen the use of energy efficiency programs as a legitimate, predictable, and reliable resource for achieving peak demand savings. The renewed and growing emphasis on energy efficiency as a utility system resource requires increased effort at measuring and documenting those impacts. We see some evidence that this shift in evaluation priorities is already occurring, a development that we encourage. This increased need for measurement and documentation of peak demand impacts must, of course, be done in a practical and cost-effective manner, such that the evaluation methods and costs do not adversely affect overall program effectiveness. But we are confident that the evaluation industry will be capable of rising to the challenge. Several reports and initiatives have already laid the groundwork for advancing the evaluation of demand impacts from energy efficiency and other DSM programs (e.g., CPUC 2006a; CPUC 2006b). We expect this trend toward better estimation and documentation of peak demand impacts to continue, for several reasons, including: (1) the increasing concern about electric system reliability and the growing trend toward the use of energy efficiency as a resource; (2) the emergence of new market structures and opportunities for monetary compensation of energy efficiency as a system reliability resource; and (3) increased adoption of advanced metering and communication technologies that make it much easier—and in many cases less costly—to evaluate peak demand impacts.

A closing and critical point is that in examining the integration of energy efficiency and peak demand impacts for program design and evaluation, it is clear that energy efficiency programs can produce substantial and cost-effective reductions in peak demand, even if the quantification of specific estimates of those effects has frequently relied on secondary data sources. The issues we raise concerning more accurate estimation of peak demand impacts of energy efficiency programs is not to suggest that the use of such programs as a resource should be diminished. Doing so would result in attendant loss of the very real benefits such programs provide. Past evaluation efforts have provided measurements of such impacts adequately in relation to program and evaluation needs and objectives. As greater importance and reliance is placed on demand-side resources within overall utility system portfolios, we see very clear and positive signs that the measurement and evaluation capabilities that will be required can be met with existing and emerging technologies and evaluation techniques. Program evaluators will have to work closely with regulators, utilities, and other stakeholders to build on the solid foundations in place for energy efficiency program evaluation to address emerging needs for program evaluation—weighing factors such as new technological capabilities, program objectives, evaluation priorities, available budgets, and evaluation costs. In this way evaluators can ensure that utility system planners and operators have the resources, data, and analytical tools in place to meet system needs reliably relative to the resource contributions from energy efficiency and related demand resources.

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APPENDIX A. DEFINITIONS

The nomenclature of DSM can be confusing, especially as pertains to energy and demand savings. While the primary metrics associated with both energy efficiency and load management programs would seem relatively simple—namely kilowatt-hours (electricity savings) and kilowatts (demand savings), the reality of program design and evaluation is such that measurement and reporting of impacts is much more complicated. There are numerous ways to report estimated program impacts. Below we define key terms used for energy efficiency, load management, and demand response programs. These definitions are taken from the *California Energy Efficiency Evaluation Protocols* (CPUC 2006a).

Coincident demand: The metered demand of a device, circuit, or building that occurs at the same time as the peak demand of the building or facility or at the same time as some other peak of interest, such as a utility's "system load." When referenced according to the utility system's peak demand, this is generally referred to as "coincident peak demand."

Demand (utility): The rate or level at which electricity or natural gas is delivered to users at a given point in time. Electric demand is expressed in kilowatts (kW). Demand should not be confused with load, which is the amount of power delivered or required at any specified point or points on a system.

Demand savings: The reduction in the demand from the pre-retrofit baseline to the post-retrofit demand, once independent variables (such as weather or occupancy) have been adjusted for. This term is usually applied to billing demand, to calculate cost savings or to peak demand, for equipment sizing purposes. For new construction, demand savings are usually calculated by comparing a "baseline" design with an alternative building plan.

Demand-side management (DSM): The methods used to mange energy demand including energy efficiency, load management, fuel substitution, and load building.

Coincident peak demand savings: Typically this is given according to either the winter or summer peak demand of a given system, whichever represents the system's maximum demand under typical conditions and for system planning purposes.

Energy efficiency measure: Installation of equipment, subsystems, or systems, or modification of equipment, subsystems, systems, or operations on the customer side of the meter, for the purpose of reducing energy and/or demand (and, hence, energy and/or demand costs) at a comparable level of service.

Energy savings: The reduction in use of energy from the pre-retrofit baseline to the post-retrofit energy use, once independent variables (such as weather or occupancy) have been adjusted for. For new construction, energy savings are usually calculated by comparing a "baseline" design with an alternative building plan.

Engineering approaches: Methods using engineering algorithms or models to estimate energy and/or demand use. These may be the only methods available for evaluating new construction programs.

Load: The amount of electric power supplied to meet one or more end-user's needs. The amount of electric power delivered or required at any specified point or points on a system.

Load diversity: The condition that exists when the peak demands of a variety of electric customers occur at different times. The difference between the peak of coincident and non-coincident demands of two or more individual loads.

Load factor: The ratio of the amount of electricity a consumer used during a given time span and the amount that would have been used if the usage had stayed at the consumer's highest demand level during the whole time. Also used as the ratio of the average load to peak load during a specified time interval.

Load impact: Changes in electric energy use or electric peak demand.

Load management: Steps taken to reduce power demand at peak load times or to shift some power demand to off-peak times to better meet the utility system capability for a given hour, day, week, season, or year.

Load shape: The time-of-use pattern of customer or equipment energy use. Typically used patterns are over a day (24 hours) or an entire year (8,760 hours).

Load shape impacts: Changes in load shape induced by a program.

Measured savings: Savings or reductions in billing determinants, which are determined using engineering analysis in combination with measured data or through billing analysis.

Metered data: Data collected at customer premises over time through a meter for a specific end-use or energy-using system (e.g., lighting and HVAC) or location (e.g., floors of a building or a whole premise). Metered data may be collected over a variety of time intervals.

Metered demand: The average time rate of energy flow over a period recorded by a utility meter.

Metering: The collection of energy consumption data over time at customer premises through the use of meters. These meters may collect information about kWh, kW, or therms with respect to an end-use, a circuit, a piece of equipment, or a whole building (or facility). End-use metering refers specifically to separate data collection for one or more end-uses in a building, such as lighting, air conditioning, or refrigeration. What is called "spot metering" is not metering in this sense, but is an instantaneous measurement (rather than over time) of volts, amps, watts, or power factor to determine equipment size and/or power draw.

Metric: A point of measurement. Any point of measurement that can be defined, quantified and assessed.

Model: A mathematical representation or calculation procedure that is used to predict the energy use and demand in a building or facility or to estimate efficiency program savings estimates. Models may be based on equations that specifically represent the physical processes or may be the result of statistical analysis of energy use data.

Monitoring (equipment or system): Gathering of relevant measurement data over time to evaluate equipment or system performance, e.g., chiller electric demand, inlet evaporator temperature and flow, outlet evaporator temperature, condenser inlet temperature, and ambient dry-bulb temperature and relative humidity or wet-bulb temperature, for use in developing a chiller performance map (e.g., kW/ton vs. cooling load and vs. condenser water temperature).

Net load impact: The total change in load that is attributable to the utility DSM program. This change in load may include, implicitly or explicitly, the effects of free-drivers, free-riders, state or federal energy efficiency standards, changes in the level of energy service and natural change effects.

Peak demand: The maximum level of metered demand during a specified period, such as a billing month or during a specified peak demand period.

Peak demand period [as defined for California; other states and systems may define this differently]: Noon to 7 p.m. Monday through Friday, June, July, August and September.

Peak load: The highest electrical demand within a particular period. Daily electric peaks on weekdays occur in late afternoon and early evening. Annual peaks occur on hot summer days. [This is defined here for California, and is typical of most—but not all—utility systems in the U.S. The Pacific Northwest is an exception, with its peak demand occurring in winter due to unique demand and supply characteristics of the region.]

Simplified engineering model: Engineering equations used to calculate energy usage and/or savings. These models are usually based on a quantitative description of physical processes that describe the transformation of delivered energy into useful work such as heat, lighting or motor drive. In practice these models may be reduced to simple equations that calculate energy usage or savings as a function of measurable attributes of customers, facilities or equipment (e.g., lighting use = watts X hours of use). These models do not incorporate billing data and do not produce estimates of energy savings to which tests of statistical validity can be applied.

APPENDIX B. INDUSTRY PROTOCOLS AND STANDARD PRACTICES FOR ASSESSING DEMAND IMPACTS

The bifurcation of DSM into two fundamentally different types of programs—load management and energy efficiency also has led to bifurcation in techniques to measure and assess the impacts of these programs. Since the focus of this report is on demand impacts of energy efficiency programs, in this section we examine industry protocols and practices for estimating energy savings (kWh) and demand savings (kW) from such programs. As we will discuss, estimating demand impacts (kW) is generally based on estimated energy impacts (for example, applying load factors or shapes to estimated energy savings). Hence to understand industry practices for estimating demand impacts requires understanding of industry practices for estimating energy impacts.

We look to two primary references describing industry protocols and best practices. These are:

- *The International Performance Measurement & Verification Protocol (IPMVP),* International Performance Measurement & Verification Protocol Committee. "The International Performance Measurement and Verification Protocol (MVP) provides an overview of current best practice techniques available for verifying results of energy efficiency, water efficiency, and renewable energy projects (page 1)." While initially developed primarily as a protocol for energy service companies (ESCOs) to verify energy savings of projects implemented for customers under either shared-savings or "guaranteed" savings contracts, IPMVP has become more widely applied to utility and related customer energy efficiency and load management programs.
- *Evaluators' Protocols, California Public Utilities Commission.* The California Public Utilities Commission recently directed the development of a comprehensive set of protocols for the "technical, methodological and reporting requirements for evaluation professionals." These protocols represent industry best practices for the measurement and reporting of energy efficiency program impacts (CPUC 2006). A companion document, which preceded preparation and publication of the *Evaluators' Protocols* is the *California Evaluation Framework* (TekMarket Works Framework Team 2004). Together these volumes present a detailed and comprehensive reference guide for evaluation professionals, program managers and others involved in program evaluation.

A key focus of IPMVP is "savings determination technique using available data of suitable quality." This protocol outlines four basic approaches to determining savings impacts of "energy conservation measures (ECMs)." These are summarized below (page 22):

- *Partially Measured Retrofit Isolation.* Engineering calculations using short term or continuous post-retrofit measurements and stipulations.
- *Retrofit Isolation:* Engineering calculations using short term or continuous measurements.
- *Whole Facility.* Analysis of whole facility utility meter or sub-meter data using techniques from simple comparison to regression analysis.
- *Calibrated Simulation:* Energy use simulation, calibrated with hourly or monthly utility billing data and/or end-use metering.

The above techniques all can be applied to determine energy savings (kWh) of ECMs and the protocol details these different approaches and discusses their applicability to different types of measures. IPMVP provides surprisingly little description or discussion of determining demand (kW) savings from ECMs. Primary sources of data to determine energy savings are utility metering and billing records. However, such data generally have limited use for determining demand impacts. The protocol notes, "Where changes to electric demand represent a significant amount of the calculated cost savings, the utility bill recorded demand may not be an adequate source of data due to the difficulties of deriving accurate models from single monthly demand readings (page 28)." Instead, IPMVP describes measurement issues for electric demand this way:

> Electric demand measurement methods vary amongst utilities. The method used by any sub-meter or modeling routine should replicate the method the power company uses for the relevant billing meter.

Utilities typically only measure electric power demand and/or time-of-use for medium to large commercial and industrial customers—the specific threshold varies among utilities, and there is growing interest and use of time-differentiated metering for residential customers.[10] However, reliance on utility metering data for power demand is still primarily limited to larger customers. And even then, isolation of specific ECMs from facility-wide metering may require specific sub-metering or other techniques. IPMVP does not describe approaches for estimating demand impacts for non-demand-metered customers.

The *California Evaluators' Protocols* and *The California Evaluation Framework* provide greater detail on techniques for estimating energy and demand impacts from energy efficiency and other customer demand-side measures and programs. While these reference manuals have been developed specifically for evaluation in California, they can well be considered a standard reference for evaluation of energy efficiency programs anywhere. These reference documents were developed by a large set of leading evaluation experts from across the U.S.; hence these materials have widespread application to evaluation of customer energy efficiency and load management programs.

The *California Evaluation Framework* outlines two basic approaches to impact evaluation:

- Billing Analysis: Use of customer billing (metering) data to estimate program impacts by comparing average energy use from pre-installation data to post-installation data. A common method within this category is the use of "normalized annual consumption" (NAC).

[10] Clearly advances in metering and communications technologies are opening up new opportunities for utilities to use time-of-use metering and demand metering for smaller commercial and residential customers. There are, in fact, a limited number of such applications in practice on either a pilot or full-scale basis. There is a growing interest in and application of time-of-use pricing or other time-differentiated pricing systems in conjunction with both these new technologies and with new market and pricing structures. However, such changes still comprise a relatively small fraction of total utility customer accounts.

- Engineering Analysis: Use of basic physical laws and equations to calculate energy and demand impacts. Input data to engineering models may include manufacturers' specifications, field testing and other research.

The *California Evaluators' Protocols* further describe two classes of evaluation methods that set the minimum allowable methods estimating "gross energy impacts" at the "basic rigor" level. These two classes are more specific methods within the two basic approaches given above. These specific methods are (page 27):

- Simple Engineering Model (SEM).
- Normalized Annual Consumption (NAC).

The California Evaluators' Framework defines "simple engineering models" this way (page 124):

> Simple engineering models and algorithms are typically straightforward equations for calculating energy and demand impacts of non-weather dependent energy efficiency measures, such as energy efficient lighting, appliances, motors, cooking equipment, etc. Simple engineering models are generally not used for weather dependent measures such as building envelope and HVAC measures; these measures are generally analyzed using building energy simulation models. However, virtually all measures can be estimated using a simple engineering model, provided weather or load dependent parameters are developed by a more sophisticated method. Simple models also require knowledge of the efficiency and baseline operating conditions for the equipment that existed before the energy efficiency investment.

The use of simple engineering models generally does not involve extensive post-installation measurement and verification. Data most likely to be measured are usage patterns (such as verifying hours of operation though data loggers) and checks of equipment operation, such as power demand of new equipment (motors, fans, lighting, etc.). In many cases, administrators of energy efficiency programs use simple engineering models as the basis to develop "deemed savings" values. Such sets of data are used to streamline the quantification and estimation of savings values for selected program measures. In Section [NN] we present case studies of states that used deemed savings as part of their evaluation frameworks to illustrate how this approach is used.

"Normalized annual consumption (NAC)" is a method that relies on utility billing and metering data to determine energy use adjusting for weather effects. As described in the *California Evaluators' Protocols,* NAC is a regression-based method that uses monthly utility billing data (kWh or therms) along with weather data and other exogenous variables to develop estimates of annual energy. NAC analysis is typically performed using statistical software. It is the most prevalent method for determining energy savings impacts for residential whole house and retrofit programs, such as impacts from building shell and heating system improvements.

Evaluating demand (kW) impacts from energy efficiency measures and programs generally builds upon the estimated energy (kWh) savings determined via engineering models or billing analysis. The *California Evaluators' Protocols* outline different methods for "Gross Demand Evaluation." The key difference between these levels of rigor is the use of primary versus secondary data. Below we summarize these protocols (From Table 2, page 33):

> The "Basic Rigor Level" relies upon secondary data for estimating demand impacts as a function of energy savings. To estimate demand impacts, end-use savings load shapes or end-use load shapes from reliable sources are applied to the estimated energy savings impacts. These sources include a database that has been developed for California's programs (the "Database of Energy Efficient Resources" or "DEER"), allocation factors developed from forecasting models or simulations performed by the California Energy Commission or utilities, or other studies as approved through California's evaluation plan review process.
>
> The "Enhanced Rigor Level" relies upon primary impact data specific to the installed measures. Such primary demand impact data must be collected during the peak hour during the peak month for the utility system peak. Sampling requirements can be met at the program level, but reporting must be done according to different climate zones (as defined by the California Energy Commission's climate zone classification).

The *Evaluators Protocols* describe 3 primary methods for primary data collection:

- Use of a regression model specified to measure program impacts for peak periods using either interval metering data or time-of-use/demand metering to estimate program gross demand. The metering here is aggregated at the particular site or facility as used for billing purposes (data are from utility metering of the customer' facility).
- Conducting field measurements of peak impacts. This requires spot or continuous metering/measurement of the equipment at peak pre- and post retrofit periods (peak periods as defined by the utility's system peak). This metering is generally specific to retrofit equipment at a site; sampling and modeling approaches may then be used to estimate program-wide impacts.
- "Experimental design with primary data collection." Use of random sampling and primary measurement to compare treatment and non-treatment groups. The experimental design requires measured energy savings during peak periods through either interval data or spot/continuous metering of samples from treatment and non-treatment groups. This approach has not been used widely within the field of energy efficiency program evaluation.

APPENDIX C. STATE POLICIES AND APPROACHES FOR ESTIMATING DEMAND IMPACTS FROM ENERGY EFFICIENCY PROGRAMS

In Appendix B we examine industry protocols for estimating demand and energy impacts from energy efficiency programs, which include protocols established and used in the State of California. In Appendix C we present selected examples of how other states and regions approach evaluation of energy efficiency programs to estimate energy and demand impacts. These examples generally take the more general protocols and guidelines and provide much more detailed guidelines and reference data to be used for quantifying program impacts. These examples further illustrate how evaluators quantify such impacts as necessary to determine program cost effectiveness and meet other resource and regulatory requirements.

New Jersey

As part of its electric utility industry restructuring, New Jersey created a statewide public benefits program, "The New Jersey Clean Energy Program." Initially the program was administered by the state's distribution utilities, but in 2005 the Board of Public Utilities took over the responsibility for program administration.

In creating the initial statewide program, the utilities submitted compliance filings in 2001 that proposed "New Jersey's Clean Energy Program Protocols to Measure Resource Savings." As described by the Board of Public Utilities in adopting these protocols:

> The proposed Protocols provide the basis for determining the energy savings or renewable energy generation from New Jersey's Clean Energy Program energy efficiency and renewable energy programs. The Protocols are used to provide the Board with the program impacts by which the Board can determine program performance and environmental benefits (BPU 2004—Order in Docket No. EO04080894).

In adopting these protocols the BPU also called for the creation of a "Protocols Oversight Group" to be comprised of representatives of the Division of Ratepayer Advocate, the Department of Environmental Protection and "other interested parties." This group is charged with the responsibility to "recommend changes and updates to the Protocols as required." Such changes include proposing new protocols as all existing and new programs must have a measurement and verification protocol in place.

The following passage summarizes the uses and references for the Protocols:

> These protocols use measured and customer data as input values in industry-accepted algorithms. The data and input values for the algorithms come from the program application forms or from standard values. The standard input values are based on the best available measured or industry data applicable for the New Jersey Programs. The standard values for most commercial and industrial (C&I) measures are supported by end use metering for key

> parameters for a sample of facilities and circuits, based on the metered data from the JCP&L Shared Savings Program.

The Protocols add:

> In general, energy and demand savings will be measured using measured and customer data as input values in algorithms in the protocols, tracking systems, and information from the program application forms, worksheets and field tools.

The New Jersey Protocols classify “types of measures” according to three broad categories in terms of the degree of variability from standard input data for the measure. The table below (taken from the Protocols (NJ BPU 2004)) defines these categories and describes the applicable protocols and general approaches to estimating savings. It also gives examples.

Summary of Protocols and Approaches

Type of Measure	Type of Protocol	General Approach	Examples
1. Standard prescriptive Measures	Standard formula and standard input values	Number of installed units times standard savings/unit	Residential lighting
2. Measures with important variations in one or more input values (e.g., delta watts, efficiency level, capacity, load, etc.)	Standard formula with one or more site-specific input values	Standard formula in the protocols with one or more input values coming from the application form, worksheet, or field tool (e.g., delta watts, efficiency levels, unit capacity, site-specific load)	Some prescriptive lighting measures (delta watts on the application form times standard operating hours in the protocols. Residential electric HVAC (change in efficiency level times site-specific capacity times standard operating hours Field screen tools that use site-specific values
3. Custom or site-specific measures, or measures in complex comprehensive jobs	Site-specific analysis	Greater degree of site-specific analysis, either in the number of site-specific input values, or in the use of special engineering algorithms	Custom Industrial process Complex comprehensive jobs

Baseline estimates for most prescriptive measures (which include numerous household technologies and appliances) are simply done as taking the delta (change in) kilowatt and kilowatt-hour values of standard products versus the high efficiency products replacing them as the result of programs. Such baseline estimates for these types of measures are to be updated as changes occur in codes and standards, as well as industry practices and markets for these products.

The Protocols outline approaches and algorithms for estimating coincident peak demand savings, specifically:

> Annual electric energy savings are calculated and then allocated separately by season (summer and winter) and time of day (on-peak and off-peak). *Summer coincident peak demand savings [emphasis added]* are calculated using a demand savings protocol for each measure that includes a coincidence factor. Application of the coincidence factor converts the demand savings of the measure, which may not occur at time of system peak, to demand savings that is expected to occur during the summer on-peak period.

The seasonal and daily periods used to allocate energy and coincident peak demand savings are based on the "best fit" for the seasonal avoided cost patterns for electric energy and capacity. For the PJM system (the broader mid-Atlantic region served by PJM, which includes New Jersey) the summer period June through August is when highest historical avoided costs (peak capacity) have occurred. The table below (from the Protocols) gives the seasonal and daily differentiation of energy and coincident peak demand savings.

	Energy Savings	**Coincident Peak Demand Savings**
Summer	May through September	June through August
Winter	October through April	NA
On peak (Mon-Fri)	8:00 am to 8:00 pm	12 pm to 8 pm
Off peak (weekends and holidays)	8:00 pm to 8:00 am	NA

New York

The "New York Energy $mart Program" is the state's public benefits energy program, which is administered by the New York State Energy Research and Development Authority (NYSERDA). Within this broad umbrella are numerous specific Energy $mart Programs for residential, commercial, industrial and agricultural customers. To estimate energy and demand savings for a number of these programs, NYSERDA uses the "Deemed Savings Database," which has been developed by Nexant, a contractor. The use of this database are for programs that include measures most amenable to a deemed savings approach—that is, measures that are relatively standard. More complex, customized types of measures are not included as they require specific analyses. "Deemed savings are a collection of pre-approved measures for which NYSERDA has calculated stipulated savings values," according to the Nexant guide to the "Deemed Savings Database." This database includes deemed savings, costs and related data for the following New York Energy $mart Programs:

- New Construction Program

- Smart Equipment Choices Program
- Loan Fund Program
- Keep Cool Program
- ENERGY STAR® Products Program
- Residential ENERGY STAR® Marketing Program
- ENERGY STAR® Bulk Purchasing Program

Estimation of impacts from other programs relies on other evaluation approaches rather than deemed savings.

Pacific Northwest Electric Power and Conservation Council: Regional Technical Forum

The Pacific Northwest has a relatively unique utility industry structure stemming from the role that the Bonneville Power Administrations (BPA) plays as a major power supplier. [11] BPA markets wholesale power to the region's public and private utilities, as well as to some large industries. BPA supplies the region with about one half of its total electricity and also operates about three-fourths of the region's high voltage transmission network. A regional electric system planning organization, "The Northwest Power and Conservation Council," was established in 1980 to guide BPA's investments, decision-making and operations.

BPA and the area's public and private utilities have been serving customers through energy efficiency programs for over 20 years—achieving a total impact of about 750 "average megawatts."[12] Because of the region's high share of hydropower, peak demand savings have not been and are not generally a high priority for customer energy programs. Hydropower-dominated systems are generally "energy constrained," not "peak demand" constrained as is more typical with utility systems reliant on thermal-based power generation (generally coal, natural gas, and nuclear).

The need for consistent reporting and verification of results from energy efficiency programs across this large region served by numerous utilities and other providers led to the creation of the "Regional Technical Forum (RTF)" in 1999. RTF is an advisory committee comprised of a diverse set of stakeholders who work together "to develop standards to verify and evaluation energy conservation savings." (from "About the RTF" webpage on nwcouncil.org.).

The NPCC established four goals for RTF, all of which address measurement and quantification of energy and demand impacts of customer demand-side management programs. The RTF's goals are (from its Charter):

[11] The "Pacific Northwest" region served by BPA comprises the states of Washington, Oregon, Idaho and the western part of Montana. BPA also markets power outside this region, such as to California.

[12] An "average megawatt" is actually a unit of energy used by convention in the Northwest because of its large reliance on hydropower. An "average megawatt" is the amount of energy produced by 1 megawatt output over an entire year—8760 hours—-or 8760 megawatt-hours.

- Develop standardized protocols for verification and evaluation of energy savings and the performance of renewable resources;
- Track regional progress toward the achievement of the region's conservation and renewable resource goals;
- Provide feedback and suggestions for improving the effectiveness of the conservation and renewable resource development programs and activities in the region; and
- Conduct periodic reviews of the region's progress toward meetings its conservation and renewable resource goals at least every five years.

To achieve these goals, NPCC also charged RTF to develop:

- A list of eligible conservation measures and programs, including estimating savings associated with these measures and programs, as well as the estimated regional power system value associated with the savings;
- A process for updating the list as technology and standard practices change and an appeals process through which customers can demonstrate that different savings and value estimates should apply;
- A set of protocols by which the savings and system values of measures/programs not on the list could be estimated (generally from large, complex commercial or industrial projects); and
- Recommended protocols for measurement and evaluation of savings or production.

In meeting these recommendations, RTF has developed a number of technical reports and references. One key reference is a catalog, "Conservation Measures and Activities Eligible for Bonneville's Conservation and Renewable Resources Rate Discount." This catalog includes 24 residential sector measures and activities, 20 commercial, 27 industrial, 29 agricultural, 6 utility system and 5 "other." The listings in this catalog are generally more of a broad descriptor of a particular eligible end-use of energy, such as "Residential Water Heaters" or "Office Equipment and Plug Loads." The catalog also includes "Defined Programs," which generally are umbrellas for numerous measures for comprehensive, multi-end use programs, such as "WeatherWise" or "Long Term Super Good Cents®. Such programs address multiple end-uses in existing or new homes.

To arrive at specific estimates of energy and demand savings, RTF has developed "Supporting Data Files," a set of spreadsheet files with technical data on specific products and technologies, such as "ENERGY STAR exit signs" or "ENERGY STAR Clothes Washers—Commercial Laundry (Coin-op)." The datafields within these database files include the data necessary to estimate costs and benefits according to different perspectives of interest. Energy savings (kWh) and "system coincident peak reduction" (kW) are included for each measure, along with costs, performance and other measure data useful to program and system planners.

Texas

Texas's restructuring act (the Public Utility Regulatory Act passed in 1999) includes provisions that require electric utilities to administer energy savings incentive programs to achieve at least a 10% reduction in annual load growth through improved energy efficiency. Each utility is required to file an annual energy efficiency to demonstrate such compliance. These reports are to include the following required data:

- Load data within the applicable service area;
- The reduction in peak demand and energy savings attributable to energy efficiency programs implemented according to relevant substantive rules of the title (§25.181 and §25.182) in kilowatt (kW peak demand reduction) and in kilowatt-hours (kWh energy savings) by county, by type of program and by funding source;

The utilities are required to offer programs selected from a set of "standard offer program" templates in addition to some broader market transformation programs.

The utilities rely on a set of deemed savings values to estimate the energy and demand savings of their programs. The Public Utility Commission of Texas has approved these savings values based on its review of petitions and related comments filed by the utilities and other interested parties in a proceeding before the PUCT (Project No. 22241). The deemed savings values include consideration of 4 distinct regions within the state for all climate-sensitive measures.

Substantive Rule §25.181 requires measurement and verification (M&V) audits of the utilities' estimated energy and demand savings. The most recent audit was completed in September 2006 (Summit Blue Consulting and Quantec, LLC 2006) of the utilities' 2003 and 2004 annual reports of program savings. This M&V review is primarily a "desk audit"—meaning that the scope of work did not include any kind of independent impact evaluation of the programs. Instead, the audit is primarily a review of the utilities' savings estimates based on interviews, program databases and paper records. The report specifically states, "No on-site inspections, metering, or customer billing analyses were conducted." The audit found that approximately 99% of the "claimed savings were verified."

The audit also reviewed methodologies and references for selected deemed savings estimates. As stated in the audit:

> The objective of this review was to trace the savings assumptions for key measures, in order to determine if the assumptions appear to be reasonable and appropriate for the applications for which they were used within the programs reported by the utilities. Deemed savings values, many of which were developed by Frontier Associates [a contractor with PUCT], are filed with the PUCT and the public had an opportunity to comment of the savings values.

The audit found that many of the deemed savings values are "reasonable," although the audit recommended that further review and analysis be conducted for certain measures to obtain more accurate estimates of savings.

The deemed savings values are used only for energy efficiency measures installed by residential and small C&I customers participating in utility programs. For the "Commercial and Industrial Standard Offer Program," which provides rebates and related services to C&I customers for making energy-efficient improvements to larger end-use equipment, systems and applications, the PUCT has established "Measurement and Verification Guidelines (PUCT ….get full citation). These guidelines are intended to be used for developing project-specific measurement and verification plans, which are required to be approved by the sponsoring utility and adhere to the *International Performance Verification and Measurement Protocol.* The guidelines include "simplified M&V approaches" and "full M&V approaches." The "simplified M&V approaches" are based on engineering calculations using typical equipment characteristics and operating schedules developed for particular situations. Stipulated values for data such as operating hours and equipment efficiencies may be used. Project measures must meet certain criteria to follow the simplified approach, which is used for the following types of projects: lighting efficiency upgrades, lighting controls, cooling efficiency projects, motor efficiency projects and variable speed drive motor retrofits. "Full M&V approaches" employ end-use metering, billing regression analyses or computer simulation to estimate energy and demand savings using a higher level of rigor than for the simplified M&V approaches. Full M&V approaches are used for more customized and specialized customer applications of a variety of end-use systems within buildings and facilities.

Vermont

"Efficiency Vermont" is the statewide public benefits program created to provide energy efficiency programs to all utility customers. The program is administered and provided by a non-utility organization, Vermont Energy Investment Corporation (VEIC), under contract directly the Public Service Board of Vermont. Specific energy savings objectives are built into VIEC's contract; there are financial incentives for VEIC based on how well it meets the objectives.

Like other states profiled in this section, Efficiency Vermont uses a standard reference for estimating program impacts and results. Specifically, the "Technical Reference User Manual (TRM), No. 4-19" (Efficiency Vermont 2003):

> …[P]rovides methods, formulas an default assumptions for estimating energy and peak impacts from measures and project promoted by Efficiency Vermont's energy efficiency programs.

As with other state and utility programs, reliance on this standard reference helps assure consistency and transparency of the savings impact estimates.

APPENDIX D. CASE STUDIES OF ENERGY EFFICIENCY PROGRAMS WITH SIGNIFICANT, MEASURED DEMAND IMPACTS

San Francisco Peak Energy Program
City of San Francisco and Pacific Gas & Electric Company
Program type/sector: Comprehensive Portfolio
Technologies/end-uses: Multiple

Program Description

The San Francisco Peak Energy Program (SFPEP) started in December 2003. The primary goal of the program was to achieve a minimum of 16 MW (gross) load reduction coincident with San Francisco's summer daytime peak, and to achieve similar reductions in winter evening peaks by 2005. The SFPEP projected savings of 22.8 MW gross peak reduction in the summer and 16.1 MW during the winter peak. For San Francisco, the winter peak period (from Nov. 1 through April 30) was 5-7 PM, and the summer peak period (from May 1 through Oct. 31) was 1-3 PM. The program was officially closed on Feb. 28, 2005. Final program tracking (through Feb. 28, 2005) indicated that 45% of demand goals and 55% of energy goals were achieved.

The SFPEP was a partnership between the City of San Francisco and the Pacific Gas and Electric (PG&E) Company. The partnership was designed to create new ways to capture energy savings opportunities that might otherwise be lost. The SFPEP focused on four main program elements that built on PG&E's existing programs:

- Cash Rebates for Business—primarily for small commercial customers
- Standard Performance Contracting—primarily for large commercial and industrial customers
- Single Family Direct Install—primarily for residential customers in houses
- Multi Family Rebates—primarily for residential customers in multiplexes

Evaluation Methods and Results

The impact evaluation of this program did not correspond directly to any of the International Performance Measurement and Verification Protocol (IPMVP) options. An alternative method was used that relied on developing program-specific adjustments to the ex-ante savings values. The approach was similar to IPMVP Option A (Partially Measured Retrofit Isolation) in that it used partial short-term field measurement of energy use to verify or adjust ex-ante energy and demand savings estimates for measures installed. Some performance parameters were stipulated or based on secondary data, or estimates were included in ex-ante calculations. Engineering adjustments were made to specific measure savings and extrapolated to the population of installed measures for the program element. The evaluation relied extensively on data, reports and other information provided by the PG&E and the City of San Francisco. The evaluation also included a review of other California program results and secondary data to confirm the evaluation approach.

The impact evaluation focused on four key program elements that tracked energy savings (in order of contribution to program gross kW savings):

- Cash Rebates for Business Customers
- Standard Performance Contract (SPC)
- Single Family Direct Install (including a torchiere exchange program)
- Multi-Family Rebate

The impact evaluation verified measure installations, metered key measures to develop end-use load shapes, and recalculated peak demand and energy savings estimates for each program element. The estimation process included several distinct steps:

- Review of program participation data
- Review of savings calculation methods and assumptions as contained in program documentation and reference sources
- Reconciliation of the savings calculation methods/assumptions with program savings estimates
- Compilation of participation data and verification of methods and assumptions in an analytic database
- Identification of measure performance variables for supplemental research and analysis
- Conducting on-site verification inspections and data collection
- Conducting supplemental analyses of key variables as required to provide additional resolution in savings estimates
- Developing adjustments to savings calculation methods/assumptions based on supplemental analyses and data collection, including adjustments to measure counts, hours of operation, and coincidence with peak
- Compilation of evaluation data in analytic database
- Re-calculation of program savings and summarization of results by measure type, and market segment
- Comparison of results with ex-ante savings values and recommending adjustments to the results as necessary

On-site data collection activities were used to verify measure installations and supplement the existing dataset, and to confirm selected variables used in the savings calculation process. On-site data collection activities varied by program, depending on the distribution of savings among various program measures, and whether data logging activities were undertaken to assess load profile metrics. An initial review of program participation revealed that the largest fraction of participation savings were from lighting measures and, therefore, the evaluation focused in-field data collection on confirming lighting performance variables through lighting run-time hour data logging. The SPC had a high proportion of HVAC/refrigeration measures and detailed on-site studies were conducted on these measures.

After adjustments to savings calculation assumptions based on metered data collection and supplemental analyses were made, the evaluation team then statistically adjusted the values, based on results of telephone surveys and on-site verifications with larger participants. The results of these analyses were then compared with PG&E's measure savings work papers and secondary sources to estimate adjustments to ex-post savings by program element.

A summary of the program planned, recorded (ex-ante), and evaluation adjusted (ex-post) estimated energy and demand impacts are contained the tables below. The original program design savings targets (goals) were developed as gross targets by the City of San Francisco; the program reported savings (ex-ante) were recorded as net by PG&E, and savings adjustments were applied during the evaluation process to the ex-ante numbers at the measure level, then summed for each program. These ex-post net savings were then re-calculated as ex-post gross savings by dividing the adjusted net savings by the net-to-gross (NTG) ratio previously applied.

Table D-1. Comparison of Gross Program Goals and Ex-Post Savings

Program Element	Gross MW (goals)	Gross MW (ex-ante)	Summer Gross MW (ex-post)	Winter Gross MW (ex-post)	Gross MWh (ex-ante)	Gross MWh (ex-post)
Cash Rebates for Business	18.65	7.17	6.60	6.60	39,814	38,025
SPC	2.10	4.26	4.26	4.73	31,336	31,336
Single family	0.15	0.26	0.29	0.54	2,012	2,277
Multi-Family	0.40	0.24	0.24	0.24	1,832	1,832
TOTAL	21.32	11.93	11.40	12.11	74,994	73,470

Table D-2. Comparison of Net Program Goals, Ex-Ante and Ex-Post Savings

Program Element	Net MW (goals)	Net MW (ex-ante)	Summer Net MW (ex-post)	Net MWh (ex-ante)	Net MWh (ex-post)
Cash Rebates for Business	17.90	6.88	6.34	38,222	36,504
SPC	1.11	2.26	2.26	16,608	16,608
Single family	0.13	0.23	0.26	1,791	2,026
Multi-Family	0.36	0.21	0.21	1,630	1,630
TOTAL	19.50	9.58	9.07	58,251	56,768

While the stated summer and winter demand reduction target was a minimum of 16 MW gross demand reduction, the evaluation indicated that about 71% of that goal was achieved in the summer and about 76% in the winter for the 2004 program year. Two energy efficiency measures contributed particularly to increased winter peak reductions: adjustable speed drives on HVAC equipment in the commercial sector and torchieres for residential lighting.

The evaluation also looked at the measures that contributed significantly to program savings for each of the four program elements for which impacts were evaluated (see Tables D-3 through D-6).

Case Rebates for Business Program

In the Cash Rebates for Business Program (see Table D-3), the high impact measures accounted for 75% of kWh savings and 75% of kW savings. Key measures saving peak demand were the premium T-8/T-5 lamp and ballast retrofits on T-12 systems, wall and ceiling mounted occupancy sensors, and new door gaskets on coolers and freezers.

Table D-3. Summary of High Impact Measures in Cash Rebates for Business Program

Measure Code	Measure Description	Number of units installed	Net kW saved	% of kW program savings	Net kWh saved	% of kWh program savings	% of rebates
L290	4-foot premium T-8/T-5 Lamp & Electronic Ballast replacing T-12 lamp & efficient magnetic ballast	199,266	2,203	32	11,158,510	29	62
L83	Wall or ceiling mounted occupancy sensors for area lighting	3,456	1,265	18	2,616,518	7	6
R2	Strip curtains for walk-in coolers	49,103	1,256	18	11,003,050	29	5
L137	High efficiency LED exit signs	6,818	278	4	2,299,750	6	8
R50	Door gasket replacements on cooler and freezer doors	27,948	170	2	1,490,484	4	4
Total			5,173	75	25,568,312	75	84

Of these high impact measures in the Cash Rebates for Business Program, a large percentage of refrigeration gasket installations had been verified by program personnel, so field work for this evaluation focused on T8 lighting retrofits and occupancy sensor installations. This activity included two components: (1) verification of measure installation rates, and (2) verification of annual operating hour assumptions. Verification of measure installation rates was accomplished through on-site inspections. Verification of annual operating hour assumptions was accomplished through the installation of data loggers at multiple sites over both the winter and summer peaking periods. This allowed an analysis of both the net operating hours and when peak demand occurred in San Francisco.

Standard Performance Contract Program

In the Standard Performance Contract (SPC) Program (see Table D-4), the high impact measures accounted for 81% of kWh savings and 78% of kW savings. Key measures saving summer peak demand were T-8 fluorescent lamps, building insulation, adjustable speed drives for both process and HVAC applications, and changes from incandescent to fluorescent lamps.

Table D-4. Summary of High Impact Measures in SPC Program

Measure Description	Total rebates paid ($)	Net summer kW saved	% of net summer kW saved	Net kWh saved	% of net kWh program saved	% of rebates
Change/add other equipment	799,199	498	22	2,601,574	16	18
T-8 fluorescent lamps	495,499	453	20	2,689,065	16	11
Insulate building shell (ceiling, walls)	283,183	223	10	779,171	5	6
HVAC Adjustable Speed Drive	929,723	212	9	3,070,480	18	21
Add high efficiency chiller	481,170	163	7	1,298,221	8	11
Incandescent to fluorescent - indoor	143,985	137	6	751,895	5	3
Process Adjustable Speed Drive	382,053	79	4	2,248,964	14	8
Total	3,514,811	1,765	78	13,439,370	81	78

In the SPC Program, each SPC site already received substantial site verification of measure installation as part of the program implementation process—including a pre-installation baseline confirmation and post-installation inspection Accordingly, the evaluation team concluded that all measures installed through the program had been thoroughly documented and accounted for in the M&V reports. Data loggers were placed on adjustable speed drives since they played an important role in reducing kWh and kW because of their impact on high use motor loads.

Single Family Direct Install Program

In the Single Family Direct Install Program (see Table D-5), four measures were recorded through the program tracking data bases. It is interesting to note that the ENERGY STAR-rated interior hardwired CFL fixtures accounted for 69% of the rebates and yielded 33% of program demand savings while the ENERGY STAR torchiere turn-ins accounted for only 11% of the rebates but yielded 42% of program demand savings.

Table D-5. Summary of Impact Measures in Single-Family Direct Install Program

Measure Description	Number of units	Net kW saved	% of net kW saved	Net kWh saved	% of net kWh saved	% of rebates
ENERGY STAR torchiere turn-ins	3,400	110	42	889,099	44	11
ENERGY STAR interior hardwired CFL fixtures	8,773	87	33	698,189	34	69
CFLs—20 watt	6,873	53	20	429,778	21	6
ENERGY STAR programmable thermostat	2,081	14	5	9,260	0	14
Total	21,127	264	100	2,026,326	100	100

In the Single Family Direct Install Program, evaluation efforts focused on two areas: (1) hours of use and (2) number of units installed or used. For screw-in CFLs, CFL hardwired fixtures, and programmable thermostats, on-site inspections and telephone survey results were compared with the program database for hours of use and installed fixtures. Data loggers on torchieres were used for verifying program assumption on hours of use.

Multi-Family Rebate Program

In the Multi-Family Rebate Program (Table 6), nine measures were recorded through the program tracking data bases. It is interesting to note that the ENERGY STAR-rated interior hardwired CFL fixtures accounted for approximately 85% of demand and energy savings.

Table D-6. Summary of Impact Measures in Multi-Family Rebate Program

Measure Description	Number of units	Net kW saved	% of net kW saved	Net kWh saved	% of net kWh saved	% of rebates
ENERGY STAR interior hardwired CFL fixtures (30 watts) 3.5 hrs	17,763	175	83	1,413,647	87	85
ENERGY STAR interior hardwired CFL fixtures (16 watts) 3.5 hrs	1,623	10	5	81,194	5	8
ENERGY STAR exterior hardwired CFL fixtures (27 watts) 8.2 hrs	395	10	5	76,807	5	1
ENERGY STAR programmable thermostat	1,242	9	4	5,527	0	5
ENERGY STAR exterior hardwired CFL fixtures (13 watts) 8.2 hrs	319	4	2	31,440	2	1
ENERGY STAR interior hardwired CFL fixtures (16 watts) for common areas	29	1	1	9,948	1	0
ENERGY STAR interior hardwired CFL fixtures (30 watts) for common areas	9	1	0	4,912	0	0
T-8 interior lamps with electronic ballasts (4 feet)	76	1	0	5,073	0	0
T-8 interior fixtures for garage areas	25	0	0	1,676	0	0
Total	21,481	210	100	1,630,223	100	100

In the Multi-Family Rebate Program, evaluation efforts focused comparing on-site inspection of installations with those reported in the program tracking database. Similarly, evaluation of self-reported hours-of-use for fixtures were compared with on-site inspection and survey data.

Lessons Learned and Transferability

The greatest peak demand savings resulted from those programs aimed at the commercial sector, although some peak demand savings occurred in the residential sector, as well. A variety of technologies can be used for reducing peak demand while also promoting energy efficiency. Two energy efficiency measures contributed particularly to increased winter peak reductions: these were adjustable speed drives on HVAC equipment in the commercial sector and torchieres for residential lighting. The evaluation study found that 71% of the 16 MW goal for this program was achieved in the summer and about 76% in the winter—for the 2004 program year. It is important to point out that several of the program elements did not achieve their savings goals for that year because many of the planned measures had not been installed at all or in a very limited fashion during 2004. Hence, the savings were most likely higher for these programs, if one were to include the following year (2005). And finally, many of these measures are common technologies that are available nationally and can be used in other areas around the country.

Northern California Power Agency SB5x Programs
Program type/sector: Comprehensive Portfolio
Technologies/end-uses: Multiple

Program Description

As part of the response to the California electricity crisis of 2000-2001, the Governor of California signed legislation (SB5X and AB29X) in April 2001, which appropriated $859 million for the general fund for the California Energy Commission (CEC), the California Public Utilities Commission (CPUC) and other State agencies. These funds were to be used for energy-efficiency investment programs, public education on energy efficiency, real-time meters, low-income bill assistance, and renewable energy. Starting in 2000-2001, over 63 energy efficiency and renewable energy peak electricity demand reduction and load control programs were implemented by 17 California public utilities with funding from SB5X and administered by the Northern California Power Agency (NCPA) under the auspices of the CEC. These programs implemented one or more of the following ten categories of programs in the residential and commercial and industrial (C&I) sectors:

- C&I lighting
- C&I HVAC
- C&I refrigeration
- C&I custom measures
- LED traffic signals
- Residential HVAC
- Residential CFL
- Residential refrigerator recycling
- Load control
- Miscellaneous programs

The total NCPA program budget was $8.7 million.

Evaluation Methods and Results

The measurement and verification (M&V) study of the NCPA programs focused on load impacts and free riders. Because of the large number of programs, the evaluation study focused on those program categories with the greatest share of budget and savings: e.g., C&I lighting, C&I HVAC, C&I custom, residential HVAC, and load control programs. Within program categories, the M&V focused more effort on sites with the largest share of savings. The M&V plan for each NCPA utility program relied on the International Performance Measurement and Verification Protocol (IPMVP). Each M&V plan calculated energy or peak demand savings by comparing measured kW and kWh use before and after implementation of programs, after adjusting for weather, occupancy, production, and equipment operations. Thus, adjustments were used to normalize for weather variations, or when a second shift or occupants were added, or for abnormal changes in electrical equipment usage. The M&V plans were closely linked with the NCPA project or program designs.

A statistical sample design was used to select a sample of customers or project from each program population. Samples were selected to obtain a reasonable level of precision and accuracy at the 80 to 90 percent confidence level. Samples were selected across NCPA utility service areas for similar programs. Decision-maker surveys were used to assess net savings for rebate programs (i.e., to discount gross savings for free riders). Decision-maker surveys were also used with engineering estimates to assess savings for residential CFL programs.

On-site M&V and engineering analyses were used to gather information regarding the pre-installation and as-built equipment in order to evaluation kW and kWh savings. All on-site visits included the verification of all as-built energy efficiency measures. Surveyors obtained 12 to 36 months of historical utility billing data for each site. Sites with significant savings received more effort in terms of spot, short-term, or continuous measurements to monitor hours of use (e.g., light loggers) or electrical use (e.g., data loggers). For sites with HVAC, energy management systems (EMS), or process measures, the M&V efforts included gathering sufficient information to develop calibrated simulations or spreadsheets to assess kW and kWh savings. Sites with large HVAC savings were evaluated using DOE-2.2 simulations (or eQuest) calibrated to utility billing data.

The ex-ante savings for all of the programs were 43.4 GWh and 18.9 MW. The net ex-post savings (based on measurement and evaluation) were 37.3 GWh and 15.9 MW. Thus, the net realization rates were 0.86 for kWh and 0.84 for kW. In Table D-7, we show ex-ante and ex-post gross savings (kWh and kW) for all of the program categories except for load control.

Lessons Learned and Transferability

Energy efficiency delivered significant electric system risk-reduction benefits in response to the California electricity crisis of 2000-2001. In addition to the investor-owned utilities, the municipal utilities were able to implement significant energy programs with a variety of measures aimed at both reducing energy use and summer peak demand. The savings from these measures and programs were reliable as reflected in the results from a rigorous measurement and evaluation study.

Table D-7. California Public Utility Programs

Program	# Measures	Types of Measures	Ex-Ante Energy Savings (kWh/yr)	Ex-Ante Demand Savings (kW)	M&V Energy Savings (kWh/yr)	M&V Demand Savings (kW)
C&I Lighting	125,966	T5, T6, T-8, CFL, Metal Halide, LED Exit, Delamping, Occupancy Sensors, Halogen	21,023,999	4,943.7	24,067,909	5,203.25
C&I HVAC	590	Packaged air conditioners, ground source heat pumps, and large custom air conditioning projects	5,645,055	2,482.4	4,095,475	2,236.46
C&I Refrigeration	1	Internal air-cooling refrigerator system with computer control, variable frequency and two-speed drives, and air versus water cooling	1,194,000	765	838,477	907
C&I Custom	64	Air compressors, variable speed controllers, computer monitors, vacuum pumps, motors, solar sunscreens, and photovoltaic systems	4,897,986	1,156	4,465,251	976.7
LED Traffic Signals	4,924	LED traffic signals	2,700,354	308.3	2,419,003	276
Residential HVAC	1,892	High efficiency air conditioners	2,712,291	1,893	801,358	1,053.3
Residential CFLs	72,627	CFLs	1,883,234	1950.8	4,822,624	1,463
Residential Refrigerator Recycling	1,609	Recycled refrigerators and freezers	2,431,274	335	2,706,338	582
Miscellaneous	1,609	Vender Misers, ENERGY STAR windows, sun screens, window film, whole house fans, ENERGY STAR refrigerators, conservation kits, water heater mattress pads, plug load sensors	921,903	427	454,806	240

California Appliance Early Retirement and Recycling Program
California Public Utilities Commission and Appliance Recycling Centers of America
Program type/sector: Residential
Technologies/end-uses: Refrigerators, freezers and room air conditioners

Program Description

In 2001 the California Legislature passed SB5 1-5 in response to the electricity crisis that had emerged. This legislation established funding for a number of programs designed to achieve significant energy and demand impacts quickly as a means to alleviate the pressure on the supply system. One of these programs was the California Appliance Early Retirement and Recycling Program. The program was administered by the California Public Utilities Commission, which contracted with Appliance Recycling Centers of America (ARCA) to implement the program and provide all services and program elements. This program built on a more than a decade of experience in California with similar programs addressing appliance early retirement and recycling.

The program offered customers modest monetary incentives for turning in functioning secondary or inefficient refrigerators, freezers and room air conditioners. The program contractor, ARCA, collected the appliances from the homes of participants and transported them to a recycling center for disassembly, recycling and disposal of non-recyclable components and materials. The program was offered state-wide.

Evaluation Methods and Results

ICF Consulting performed an evaluation of the program, which included assessing the program's energy and demand impacts. ICF identified "four key elements" in its computation of the program energy and demand impacts:

- Unit annual energy consumption (UEC)
- Unit peak demand
- Unit lifetime
- "Adjustment" factor ("Part-use" and "Net-to-Gross" factors): The adjustments used to estimate the net impact of the program by taking into account what program participants would have done in the absence of the program.

The evaluators reviewed relevant program evaluation literature to understand past approaches and estimates that have resulted. They reviewed seven prior evaluations of similar appliance retirement and recycling programs and found that the estimates of these parameters "have ranged widely"—from 0.245 kW/unit to 0.33 kW/unit for refrigerators. ICF's approach to the evaluation relied on both a statistical analysis of collected units and a limited amount of on-site monitoring of a small set of refrigerators collected by ARCA.

The statistical approach was based on a similar evaluation methodology used in estimating impacts from appliance early retirement programs run by Southern California Edison in the 1990s. This approach consisted of 2 main steps: (1) a regression analysis using data from two metering studies performed on sample appliances, and (2) using the results of the regression analysis to estimate "unit annual energy consumption" for each unit removed in the program, varying according to key characteristics such as age, aperage, size, configuration and defrost type. The metering studies used were conducted in 1998 and 1996 and included a total of 1,313 refrigerators and freezers sampled from selected programs and locations across the U.S. These studies were conducted in laboratory settings following Department of Energy metering protocols to yield estimated UEC values for each unit.

The evaluation also employed on-site monitoring of 40 refrigerators prior to their removal by the program. Due to some problems in creating the sample, the evaluator does not consider the sample to be random and therefore the results are not considered statistically valid. The evaluator found, however, that the results of this set of monitored units suggested UEC values less than half those obtained using the statistical approach. The evaluators were not able to reconcile this wide disparity; rather, they used ranges of key parameters to develop ranges of estimated costs and benefits.

To estimate unit peak demand reduction the evaluators used load factors applied to the annual UEC values. Past evaluations of this type of program had used this approach, and the evaluation team agreed that this was valid and effective for the purposes of this specific evaluation.[13] The load shape data used in this evaluation were from a residential appliance end-use study based on 1996 data. The evaluators found that applying the statistical approach to derivation of the UEC yielded an estimate of 0.308 kW peak demand reduction per unit. However, using the UEC estimated from on-site monitoring sample yielded an estimate roughly half of that—a value of 0.146 kW per unit (mirroring the discrepancies found for UEC). The evaluators believed this lower estimate to be "more indicative of actual program impacts," and, therefore, used it for estimating program impacts. This value also was significantly less than reported values for peak demand reduction in the seven program evaluations reviewed by ICF. They recommended that the CPUC undertake research efforts to directly monitor peak impacts of measures such as those targeted in this program.

Lessons Learned and Transferability

This program evaluation demonstrated the importance of using some measured data on both energy and demand impacts of targeted end-use technologies. In this example, the evaluators estimated energy and demand impacts roughly half that of earlier studies. The basis for this discrepancy is not clear, although the evaluators suggested that the statistical analyses applied to laboratory metering samples do not yield accurate estimates of actual unit energy consumption.

[13] The use of load factors is commonly used to derive estimated peak demand savings from estimated energy savings values, as we discussed in the body of this report.

Residential Load Research on High Efficiency Air Conditioner Replacement
Progress Energy Florida, Inc. and Florida Solar Energy Center
Program type/sector: Residential
Technologies/end-uses: Central air conditioners and heat pumps

Program Description

Florida electric utilities have sponsored many programs to encourage customers to install more efficient central air conditioners and heat pumps. Despite the number of programs and their relatively long duration in many cases, few of them have monitored and measured directly both energy use and summer peak demand impacts.

Progress Energy conducted residential load research on over 167 single-family residences in central Florida to establish baseline 15-minute data on air conditioner power consumption, interior air temperatures and appliance loads over a two year period. As part of this larger research effort, the researchers selected 5 homes as case studies of specific air conditioning retrofit measures. All project homes were metered for a full year prior to the AC retrofits to allow accurate analysis of the pre- and post-intervention periods. There were three types of AC retrofits performed for this project:

1. Change to higher efficiency single-speed equipment.
2. Change to single-speed outdoor unit with a variable speed indoor unit.
3. Change to two-stage outdoor compressors with a variable speed indoor blower

Below are specifications by site as to the AC retrofits performed:

Conventional AC Retrofits (single speed air handlers)

- Site #26: Existing central 3.5 ton A/C unit replaced with 4 ton heat pump with matching constant speed air handler.
- Site #36: Existing 2 ton water-to-air heat pump replaced with a single-speed 3-ton unit.

Variable Speed Air Handler Retrofits

Two sites featured retrofits of existing systems with high-performance two-stage compressor cooling systems with nameplate SEERS up to 18 Btu/Wh when used with a variable speed air handler.

- Site #75: Existing 4 ton central A/C unit replaced with 4 ton, two-stage heat pump with matching air handler.
- Site #38: Existing 3 ton central A/C unit replaced with 3 ton, two-stage heat pump with matching air handler.

A third site was retrofit with a variable speed air handler with a single stage cooling system:

- Site #197: Existing 2.5 ton packaged unit (combination condenser and evaporator)—nominally a 7.0 EER system—was replaced with a 3 ton system with variable speed air handler.

Evaluation Methods and Results

The researchers created three graphical evaluations of data gathered at each site for analysis of the impacts of the AC retrofits. These plots are:

1. *Average Daily Air Conditioning Consumption (kWh) Against Exterior to Interior Temperature Difference:* Average air conditioning consumption in the existing AC system compared with the retrofit system against the site measured interior to exterior temperature difference.
2. *Average Air conditioning Demand Profile Pre and Post Retrofit*: Air conditioning power demand and interior temperature profiles for month long periods in the pre and post period with matched weather conditions. In this case, "average peak demand" was defined as the "maximum daily average hourly AC electricity requirement (kilowatts) over month-long summer periods.
3. *Average Utility Peak Day Demand Profile Pre and Post Retrofit:* Utility peak day demand data before and after the retrofit—summarizing the peak hour demand reduction (over the 24 hours of the system peak demand days). This third plot was necessary to determine coincident peak demand reduction since the summer peak demand occurs when the entire utility system experiences its maximum demand during an hour. Utility system peak time occurs between 3-5 pm on peak demand days.

Table D-8 gives summary results for daily AC energy use, average peak demand and coincident peak demand savings:

Table D-8. Summary Results for Selected Sites

	Daily average AC use savings kWh	Daily average peak demand savings kW	Utility peak hour demand savings (coincident peak) kW
Site #36	11.7 (29%)	0.80 (30%)	1.26 (39%)
Site #26	28.8 (34%)	0.20 (5%)	1.33 (26%)
Site #75	29.0 (47%)	1.50 (37%)	1.61 (32%)
Site #38	21.4 (59%)	1.46 (44%)	NA
Site #197	30.3 (52%)	1.64 (49%)	2.54 (60%)

The researchers drew several conclusions from this research project:

- Typical energy and demand savings from conventional AC replacement can be expected in the range of 25%. However, proper sizing of retrofit equipment may be vital to achieving effective utility coincident peak demand reduction.
- High performance AC systems with variable speed air handlers can achieve energy savings averaging about 50% with reductions to peak demand of 35-50%.

- AC systems with variable speed air handlers showed the largest impacts to both energy and peak demand reductions. Such systems provide additional customer benefits, including better ability to provide rated air flow at different static pressures, quieter operation and improved moisture removal in humid climates.

Lessons Learned and Transferability

This research project is a prime example of a metered end-use study of a selected technology for both its energy and demand impacts. It illustrates the types of data necessary and the means, timelines and methods associated with the data collection and analysis. These types of end-use metering studies can be used as the foundations upon which to estimate larger, collective impacts from promotion of the same technologies for full-scale energy efficiency programs. Such end-use studies provide data critical to calibrate and validate models and statistical approaches used for evaluating and estimating program impacts from large numbers of participants.

AC Installer and Information Program
TXU Electric Delivery
Program type/sector: Residential
Technologies/end-uses: Central air conditioning installation practices

Program Description

Residential air conditioning comprises a large share of total residential electricity usage and summer peak demand in Texas. In recognition of this significant energy efficiency opportunity, utilities in Texas had provided rebates and other financial incentives to encourage the installation of high efficiency air conditioning equipment for many years. However, as in many states and regions, program designs in the late 90s shifted their focus to "market transformation." As a result of restructuring in Texas, the regulated distribution utilities are required to implement a portfolio of energy efficiency programs including market transformation programs and selected "standard offer" programs in order to assure uniformity in programs and services offered statewide.

The AC Installer and Information Market Transformation Program's main objective is to provide "cost-effective reduction in peak demand by helping to develop the market for proper HVAC installation practices." This program was launched in 2003 with features designed to overcome a number of market barriers, including:

- Lack of information,
- Higher up-front costs,
- Split incentives,
- Performance uncertainties, and
- Bounded rationality.

To address these barriers TXU Electric Delivery's AC Installer Program provides training and education to installers along with financial incentives. The objectives are to encourage proper unit sizing, installation, duct sealing and related measures that improve system efficiency. To ensure proper unit sizing, installers are required to perform Manual J or N load calculations. To address lack of information, the program offers several classes and training sessions, including (1) Duct Rough-In Class, (2) New Construction Class, (3) The Replacement Class, and (4) System Design Class. The Air Conditioning Contractors of America, North Texas Chapter, administers the program for TXU Electric Delivery. "Validation" is required of installed systems, which requires visual inspection, verification of installed equipment and selected testing of key parameters, including static pressure, dry- and wet-bulb temperatures, air leakage and instantaneous power demand (kW). Upon successful validation, the program administrator issues a check to the AC dealer (the incentives go to the installers, not property owners).

Evaluation Methods and Results

The program evaluation relied upon data from several sources, including extensive surveys completed of AC installers who had participated in the program in 3 program years—2003, 2004 and 2005—along with a control group of non-participating dealers. Surveys were mailed to all program year participants and the identified on-participating dealers (both within TXU's service territory and outside the service territory). The survey included questions on key parameters for the sizing, selection and installation of AC systems, including:

- Number of installations performed in the previous year (both new construction and replacement systems),
- Percentage of change-outs that were complete systems versus condenser-only changeouts,
- Distribution of new and replacement installations by SEER ranges,
- Average size (tons) for standard-efficiency versus higher efficiency units,
- R-value of installed ductwork,
- Charging techniques for TXV and capillary tube systems,
- Use of a "Duct Blaster™" or similar device in new and replacement installations,
- Materials used to seal duct connections,
- Percentage of replacement installations that were downsized, and
- Percentage of new and replacement installations that included measurements of air flow across the coil.

Participants and non-participants were asked the same core questions. There were some slight changes in the survey across the 3 program years. The survey results were used to estimate program impacts in a number of areas that affect energy and demand of systems, but additional data were needed. Field measurements conducted on samples of ENERGY STAR homes were completed to estimate the impact of performing duct diagnostics on new construction installations. For estimating the energy and peak demand savings from reducing duct leakage, the evaluation relied upon the deemed savings values approved by the Public Utility Commission of Texas. The evaluators adjusted the deemed savings values based on the measurements taken in the sample of new homes.

The tables below summarize the 2004 and 2005 AC Installer Program Impacts.

Table D-9. 2004 AC Installer Program Impacts

Program Component	Peak Demand Reduction (MW)	Energy Savings (MWH)
Higher SEER	6.47	8,420
Downsizing	1.12	
Duct sealing in new construction	8.12	12,001
Program Totals	15.71	20,421

Table D-10. 2005 AC Installer Program Impacts

Program Component	Peak Demand Reduction (MW)	Energy Savings (MWH)
Higher SEER	9.27	11,574
Downsizing	0.74	
Duct sealing in new construction	1.86	2,741
Duct sealing in replacement installations	1.62	2,387
Program Totals	13.49	16,703

Lessons Learned and Transferability

This evaluation relied on several data sources—surveys of participants and non-participants, a limited amount of field measurements and deemed savings values. The survey research was particular valuable for determining changes in AC installer practices, which was the chief objective for the program. The evaluation relied principally on the use of deemed savings values for estimating energy and peak demand savings, with some adjustments made based on survey results and the field measurements related to better duct sealing in new construction.

The evaluation notes that the savings estimates do not account for the impacts of other changes in installer practices that may be attributable to the program, including refrigerant charging, air flow optimization, duct outlet and supply sizing, and other system start-up practices. The survey results indicate some significant differences in these practices according to participant and non-participant groups. The evaluators did not estimate the energy and demand impacts of these changes, however, because of a lack of data and related difficulties in accurately quantifying such impacts. The evaluators suggested additional research on these and all installation practices as more experience is gained.

The evaluation approach used in this case is readily transferable, although the impact data are based on Texas weather and climate (factored into the deemed savings values approved by the PUCT). This program evaluation is notable as an example of estimating program impacts associated with an education and training program.

Comprehensive Hard-to-Reach Mobile Home Energy Saving Local Program
American Synergy Corporation and CAL-UCONS
Program type/sector: Residential mobile homes—low-income
Technologies/end-uses: Multiple/comprehensive

Program Description

The "Comprehensive Hard-to-Reach Mobile Home Energy Saving Local Program" was a third-party (non-utility) program implemented in 2002 and 2003 with funding through the California Public Utilities Commission. The program was developed and implemented by contractors with the CPUC, American Synergy Corporation and CAL-UCONS. The program provided comprehensive no-cost energy efficiency improvements in a total of 12,000 mobile homes in California—6,000 in the service territory of Pacific Gas & Electric and 6,000 in the service territory of Southern California Edison and Southern California Gas companies. The program installed almost 83,000 energy efficiency measures to provide measurable energy and demand savings for hard-to-reach mobile home customers. Measures installed included air conditioner tune-ups, duct sealing, infiltration reduction, programmable thermostats, compact fluorescent lamps (CFLs), efficient showerheads and faucet aerators, water heat blankets and pipe insulation.

Evaluation Methods and Results

The program evaluators used a multi-pronged evaluation, measurement and verification approach, which included:

- On-site inspections,
- Field measurements, and
- Process surveys.

Evaluation objectives included verification of installations, quantification of program impacts, and assessment of program operations to develop recommendations for improving cost-effectiveness of program services. The evaluation team randomly selected 300 program participants for data collection that included:

- On-site audits that measured energy efficiency performance, quality and persistence of installed measures;
- In-person process surveys with residents at audit sites.

The evaluators made numerous field measurements at each selected site, which included measuring power demand of air conditioners and lighting using "true RMS 4-channel power data loggers and 4-channel power analyzers" (power metering/logging equipment). To estimate load impacts for weather sensitive measures, the team used the field measurements along with engineering analysis and building simulations (EZ Sim and eQuest/DOE-2.2) calibrated to billing data. Load impacts for CFLs are based on the differences between CFLs and the incandescent lamps they replaced, and hours of operation based both on participant-reported information and lighting loggers installed at a random sample of sites. Deemed savings values with some adjustments based on field measurements and verification findings were used to estimate load impacts of low-flow showerheads, faucet aerators, pipe insulation and water heater blankets. The load impact evaluation followed the International Performance Measurement and Verification Protocols.

The ex post net first year load impacts are estimated to be 622,052 kWh per year and 3,695 kW. Table D-11 provides a break-down of these savings estimates by measure:

Table D-11. Program Ex Post Net Lifecycle Load Impacts by Measure

Measure	Savings: Kilowatt-hours	Savings: kilowatts
AC tune-up	7,008,180	823
Duct test and seal	38,773,607	1,564
Infiltration reduction	244,358	19
CFL Fixture 13-35 W	9,421,940	242
CFL Interior 15-35 W	18,912,947	854
CLF Exterior 13-35 W	3,901,080	34
Programmable t-stat	1,465,915	157
Showerhead—electric	143,464	2
Faucet aerator—electric	4,494	0
WH blankets—electric	9,167	0
Pipe insulation—electric	1,161	0
1st Year load impact	7,680,754	3,695

Lessons Learned and Transferability

This program demonstrated that low-income mobile home households can benefit from a comprehensive energy efficiency program targeted to their needs. The overall program was found to be cost-effective with a benefit cost ratio of 1.52 based on the total resource cost test. The program evaluation found a number of changes to make to the program to improve its services and increase its impact and cost-effectiveness. The evaluation used on-site metered data for an extensive set of variables. With these data, the evaluators also were able to estimate "realization rates" of ex-post (actual) versus ex-ante (predicted) energy and demand savings. They found that these rates were 0.81 +/-0.08 for kWh and 0.58 +/- 0.10 for kW. In this case the actual estimated peak demand impacts were significantly less (about 40%) than predicted, while actual energy impacts were much closer (20% less) to predicted energy impacts. Given the somewhat unique nature of the customer population served by this program, it is not appropriate to draw any generalizations about these realization rate findings to other residential customer classes, other than possibly other low-income households.

Small Commercial & Industrial Retrofit Program
NSTAR Electric and Gas Corporation
Program type/sector: Small commercial
Technologies/end-uses: Lighting, refrigeration

Program Description

The Small Commercial and Industrial Retrofit program has been offered by NSTAR since 1999. The program targets discretionary retrofit technologies—principally lighting (80% of installed measures) and refrigeration (most of the balance of installed measures) for C&I customers with an average peak demand of 100 kW a month or less. The program provides "turn-key" installation of measures; the program services cover all aspects of the lighting installation. Measures typically installed via the program include T8 lights with electronic/low power ballasts, CFLs and LED exit signs. The program provides financial incentives between 80% and 100% of the installed costs of any cost-effective energy efficiency measures identified by the initial customer audit.

Evaluation Methods and Results

A primary objective of the program evaluation was to determine realization rates for reported hours of operation for energy-efficient lighting measures and to investigate the factors that influence these rates. The hours of operation for lighting has been considered by many to be the largest source of uncertainty for estimating energy and demand impacts associated with installation of energy-efficient lighting technologies.

The study used a variety of analytical techniques, including the "engineered calibration approach," statistical sample selection, ration estimation and expansion of results, a correlation analysis of reported, observed and tracked hours of operation, and an aggregate load shape analysis of lighting operating hours by building type.

Key data collection activities included:

- Sampling: A sample design of 60 sample points was determined to yield a precision of +/-10% at a 90% confidence interval. The sample was statistically selected based on an optimization of five designated strata of accounts based on kWh savings of each account. This sample of 60 was selected from a program population of 2065 participating accounts (customers who had lighting measures installed in 2000 or 2001).
- On-site monitoring: Where possible, the evaluators installed a minimum of 5 lighting loggers per site (60 sites total) for a 4-week monitoring period to gather data relevant for lighting retrofit measures installed by the program.
- Participant surveys: The evaluators completed surveys with decision-makers at 57 of the sites. These surveys were designed to collect additional data on hours of operation and to assess the persistence of measures installed. These surveys also gathered data on participant satisfaction, business demographics and reasons for participation.

The evaluation estimated that the gross realization rate for lighting measures to be 83% with a precision estimate of +/-10.2% and the final net realization rate (accounting for free riders and free drivers) to be 76.8%. The gross energy savings across the program years were estimated to be 29,400 MWh and net energy savings to be 27,100 MWh.

The evaluators estimated demand (kW) savings from the lighting measures, including coincident savings for summer and winter peak demands. The total program demand savings across years were estimated to be 8,653 kW. Diversity factors were estimated to be 69% for summer peak and 42% for winter peak, yielding coincident peak demand impacts of 5,976 kW for summer and 3,660 kW for winter.

Lessons Learned and Transferability

The evaluation of this program provides important insights into actual lighting use patterns of small C&I customers. It revealed that data and methods used for estimating ex-ante impacts of lighting efficiency improvements yielded values that were about 20% higher than gross estimated ex-post values. Since lighting retrofits represent a significant share of many commercial and industrial energy efficiency programs, this evaluation suggests that accurate sampling and on-site metering and data logging of actual customer use patterns is important for accurate estimation of energy and demand impacts.

2003 Small Business Lighting Retrofit Programs
Massachusetts Utilities: Cape Light Compact, National Grid, NSTAR and Western Mass Electric
Program type/sector: Small business
Technologies/end-uses: Lighting

Program Description

This set of programs all offer lighting efficiency upgrades to small business customers. Each sponsoring utility delivers the programs under different names, but the approach and services provided by each program are common. The programs each work with qualified customers to identify cost-effective efficiency retrofit opportunities and provide direct installation, financial incentives and other strategies to encourage the early replacement of existing equipment with high efficiency alternatives. The programs also promote the installation of high efficiency lighting equipment for new applications. Most of these small business programs do not restrict end-use technologies to lighting; they also typically target refrigeration, domestic hot water and HVAC systems. These small business programs offer turn-key services—a single source for all the information, technical assistance and financial incentives necessary to complete system improvements. The programs are administered through several prime contractors to the sponsoring utilities.

Evaluation Methods and Results

The sponsoring utilities contracted with an independent evaluator to assess the impacts of lighting fixtures (non-control measures) installed as a result of the programs. The primary goal of the evaluation was to quantify the actual energy and demand savings due to the installation of energy-efficient lighting technologies in the 2003 program year. The utilities specified that these estimates should be to precisions at the 90% confidence level for each sponsoring utility's program and at an overall precision of +/-10% for the aggregate impact for the State of Massachusetts.

Core objectives of the evaluation were to:

- Determine summer and winter diversity factors, derived from lighting logger loadshapes;
- Determined connected kW realization rates, derived from differences in lighting counts and technologies between the observed quantity and type of lighting on-site and the appliance counts;
- Determine the kWh realization rate and hours of use realization rate from the logger data, on-site quantities and technologies observed, and application data;
- Calculate on-peak energy savings from logger data; and
- Determine hours of use by major building type across all sample points.

The impact evaluation consisted of the following steps:

- Developing an efficient sample plan for the selection of small business participants for on-site surveys and optimized to the extent possible to reach desired precision levels.

- Performing on-site assessments to verify quantities, installed technologies and hours of operation through use of time-of-use lighting loggers installed for three-week periods.
- Engineering reanalysis and estimation of kWh savings, connected kW savings, summer and winter diversified peak kW savings and on-peak energy savings.

The evaluation estimated state level total energy savings to be the following:

	Annual Energy	
Parameter	kWh	%Adjustment
Gross tracking savings	38,246,527	N/A
Controls adjustment	-290,723	-0.8
Revised tracking savings	37,955,804	N/A
Documentation adjustment	-808,080	-2.1
Technology adjustment	-1,798,013	-4.7
Quantity adjustment	661,781	1.7
Operation adjustment	-1,334,678	-3.5
Heating adjustment	-616,409	-1.6
Cooling adjustment	1,714,378	4.5
Evaluated annual energy savings	35,774,783	-5.7

The adjustments are based on the data gathered on-site as to actual installation and operation of lighting systems. The evaluators used these data to estimate adjustment factors applicable across all program participants. The "heating" and "cooling" adjustments are for interactive effects of lighting energy use with that used for heating and cooling.

The evaluation estimated state total demand impacts to be the following:

	Connected Demand	
Parameter	kW	%Adjustment
Gross tracking savings	N/A	N/A
Controls adjustment	0	N/A
Revised tracking savings	0	N/A
Documentation adjustment	0	N/A
Technology adjustment	0	N/A
Connected Demand Reduction	10,471	N/A
Cooling Adjustment	1,416	13.5
Summer Coincidence Adjustment	-2,224	-21.2
Summer Peak Demand Reduction	9,663	N/A
Heating Adjustment	-646	-6.2
Winter Coincidence Adjustment	-4,723	-45.1
Winter Peak Demand Reduction	5,102	N/A

Lessons Learned and Transferability

Small business programs are commonplace across the U.S. The most prevalent energy efficiency improvements promoted through small business programs are lighting system upgrades—more efficient fixtures, lamps, ballasts and controls. Utilities in Massachusetts have a long, well-established record of successfully delivering such programs to their small business customers. Energy-efficient lighting is a class of end-use technologies that has clear and direct impacts on reducing peak demands. This program evaluation estimated both the energy and peak demand impacts of these programs in Massachusetts using metered data. The evaluation specifically collected data necessary to estimate peak demand impacts—both for winter and summer coincident peak demands. The evaluation approach and methods are readily transferable in evaluating similar programs.

2003 Custom HVAC Installations
National Grid USA Service Company
Program type/sector: Medium and Large commercial/industrial
Technologies/end-uses: HVAC systems

Program Description

National Grid offers technical services and financial incentives to promote energy-efficient HVAC technologies and systems for large commercial and industrial customers. The nature of HVAC systems for these customers is that each system is a unique and custom design. Consequently, programs designed to increase their energy efficiency must themselves take a customized approach to analyzing, developing and implementing energy efficiency measures.

Evaluation Methods and Results

Evaluations of custom installation programs require measurement and verification of each participating site. Sampling and statistical methodologies used for more “mass market” or “standard” programs are not appropriate. These custom programs tend to be characterized by relatively few numbers of participants, but each with relatively large energy use. This NGrid program is typical, and the evaluation included just 8 participants.

A contractor, DMI, completed this evaluation for NGrid. The scope of the study was to provide annual energy savings, summer and winter diversified demand impact, and percent of energy savings that occur on-peak for each participant included in the study.

The approach used by DMI was:

- Review participant application and documentation;
- Develop a calculation methodology for energy and demand impacts;
- Develop a survey guide to collect necessary data;
- Develop an evaluation plan for each site (participant), which was to include an interview questionnaire, a list of observations to make at the site, a metering plan and a list of equipment needed to take to the site.

At the site the evaluators:

- Observed and verified installed measures,
- Interviewed customers about current operations, hours of use and the base (pre-retrofit) conditions of the equipment or systems.
- Took power measurements where required by the evaluation plan; also noting and recording other key variables, such as temperature, pressure and/or flow rate.
- Reviewed and collected customer data including hours of use, operators’ log sheets, and other available data pertinent to system operation.

Evaluation results for energy and demand savings are summarized in the tables below:

Table D-12. Annual Energy Savings: Tracked vs. Evaluated

Site	Description	Tracking (ex-ante estimates) kWh	Evaluated (ex-post estimates) kWh	Evaluated/ Tracking (%)
1	Water cooled chiller	74,390	8,142	11
2	Variable speed drives (VSDs) on rooftop unit fans	48,211	202,539	420
3	New high-efficiency roof-top units	93,079	41,772	45
4	VSDs on two 30-hp cooling tower fans	234,683	9,768	4
5	RTU with VFD and heat recovery	169,672	175,659	104
6	VFDs on chilled water pumps	175,437	144,102	82
7	VSDs on two 125-hp condenser water pumps	560,099	226,278	40
8	Chiller, tower, pumps and energy management system replacement	449,457	171,592	38
	Total	1,805,028	979,852	54

Table D-13. Summer Peak Diversified Power: Tracked vs. Evaluated

Site	Description	Tracking (ex-ante estimates) kW	Evaluated (ex-post estimates) kW	Evaluated/ Tracking (%)
1	Water cooled chiller	33.0	12.1	37
2	Variable speed drives (VSDs) on rooftop unit fans	10.0	21.3	212
3	New high-efficiency roof-top units	27.8	9.4	34
4	VSDs on two 30-hp cooling tower fans	5.2	3.3	64
5	RTU with VFD and heat recovery	20.5	45.1	220
6	VFDs on chilled water pumps	12.1	12	99
7	VSDs on two 125-hp condenser water pumps	11.9	36.3	305
8	Chiller, tower, pumps and energy management system replacement	68	26.4	39
	Total	188.5	165.9	88

Table D-14. Winter Peak Diversified Power: Tracked vs. Evaluated

Site	Description	Tracking (ex-ante estimates) kW	Evaluated (ex-post eximated) kW	Evaluated/ Tracking (%)
1	Water cooled chiller	7.9	(3.8)	-48
2	Variable speed drives (VSDs) on rooftop unit fans	8.6	24.4	285
3	New high-efficiency roof-top units	3.3	2.4	72
4	VSDs on two 30-hp cooling tower fans	35.8	0.0	0
5	RTU with VFD and heat recovery	23.5	12.7	50
6	VFDs on chilled water pumps	20.9	19.3	93
7	VSDs on two 125-hp condenser water pumps	48.7	44.7	92
8	Chiller, tower, pumps and energy management system replacement	-	-	-
	Total	150.4	99.8	66

Lessons Learned and Transferability

This evaluation clearly demonstrates the individual, customized approach necessary to accurately assess the energy and demand impacts of custom installation programs. The evaluation revealed significant differences in many of the ex-ante estimates of savings versus the ex-post findings. While in some cases there were significant differences in these values, the overall evaluation shows that these types of energy efficiency improvements do realize significant peak demand savings and energy savings.

New York Energy $mart^{SM} Peak Load Management Program
New York Energy Research and Development Authority (NYSERDA)
Program type/sector: Large commercial and industrial
Technologies/end-uses: Custom

Program Description

Unlike the other case studies in this appendix, The New York Energy $mart^{SM} Peak Load Management Program (PLMP) is not primarily an energy efficiency program. PLMP is a load management program, especially focused on enabling commercial, industrial and institutional customers to participate in demand response events called by the New York Independent System Operator (NYISO). The program also supports activities by customers to participate in alternative electricity rate structures—particularly dynamic pricing strategies.

This program was formerly named the "Peak Load Reduction Program" (PLRP) under the previous New York system benefits charge funding cycle. Going forward into the next funding cycle (5-year period beginning in 2006), the program will be known as the "Peak Load Management Program" to reflect the program's increasing focus on enhanced building automation and dynamic retail pricing strategies. In this case study we refer to the program by its old name, PLRP, as we draw upon evaluations and impacts achieved by the program as it was offered under previous funding cycles.

While energy efficiency is not the primary objective of PLRP, we include this program in our set of case studies because it contains a component—or "path"—that does specifically target "permanent peak load reductions" through energy efficiency. This well illustrates the principle that energy efficiency can yield significant peak demand reductions. When reviewing the experience of PLRP in this case study, though, it is important to keep this distinction in mind. Such a distinction affects how the program has been evaluated. It also is important to note that the New York Energy $mart Program offers a number of other programs to these same types of customers that specifically address energy efficiency as their primary objectives.

PLRP's primary objective is to enable large commercial and industrial customers to participate in demand-response programs operated by the New York Independent System Operator (NYISO). PLRP takes an integrated approach to offer customers a range of strategies for reducing peak electric requirements, including information, technical support, and incentives to invest in advanced technologies through either curtailment opportunities or through permanent electric efficiency improvements and associated demand reductions. PLRP provides incentives to customers to acquire and install demand-response-enabling technologies that then allow customers to participate in NYISO demand-response programs.

PLRP was first offered in 2001 and has been offered annually since then. The program offers incentives to participants that cover up to 75 percent (with caps) of the expenses incurred to implement measures.

The program has four main components or "paths":

- Permanent Demand Reduction Efforts (PDRE)
- Load Curtailment/Shifting (LC/S)
- Dispatchable Emergency Generator Initiatives (DEGI)
- Interval Meters (IM)

PLRP is primarily a load management program. Three of the above paths—LC/S, DEGI and IM—involve measures and services designed to enable customers to participate in demand response programs via both the necessary metering and load curtailing (shedding) technologies in place. However, a unique and innovative feature of PLRP is that it includes a path that addresses energy efficiency improvements—the “Permanent Demand Reduction Efforts”—as a means to reduce load. The PDRE path targets measures that result in base-load reductions and long-term (expected to be in place and operational for at least 5 years) coincident system peak-demand reduction. Program incentives under this program element are not intended to apply to any measures that take longer than 8 months to plan and install as NYSERDA has a number of other programs that address such energy efficiency opportunities that require lengthier planning and installation times.

The program directly places a high value on permanent demand reductions—from almost three to five times higher incentive amounts than offered for load curtailments/shifts ($475/kW in the New York City area (Con-Ed territory) and $225/kW the rest of the state). Eligible measures for the permanent demand reduction path include, but are not limited to, operation and maintenance services, HVAC, lighting systems, motors, motor drives, energy management system upgrades, advanced metering controls, and scheduling improvements. Permanent demand reduction measures must be activated in an automatic mode or as an integrated function of the operation of the building systems or equipment. Eligible project costs include engineering services, procurement and installation of capital equipment, metering equipment, and other services and equipment necessary to achieve the permanent demand reductions.

Evaluation Methods and Results

In 2003 a measurement and verification evaluation was completed on the PLRP. The evaluations primary objective was to investigate the accuracy of NYSERDA’s reported demand reduction potential (MW) due to the program. The program administrator, NYSERDA, reports a field-verified demand reduction potential for each customer who has completed installation of measures according to one of the program paths. The M&V approach was to examine a representative sample of completed projects under the program and apply these findings to all projects in the program. For each project in the sample, the evaluator developed a realization rate—the ratio of project’s ex-post (actual) savings to NYSRDA’s initial estimated savings. The realization rate is the percentage of NYSERDA-reported savings that are corroborated during the M&V evaluation review. This review consisted of interviews and site visit observations, along with review of project documentation (including engineering calculations and assumptions).

Evaluation results show that the PLRP has been very successful in achieving program goals for demand reduction. Table D-15 shows the total demand reductions achieved by each program element for 2001–2003 along with the "realization rates" (ratio of M&V-adjusted savings to NYSERDA's initial estimates of project savings):

Table D-15. NYSERDA PLRP Demand Reductions and Realization Rates 2001–2003

Program Path	M&V Evaluation-Adjusted Demand Reduction (kW)	Realization Rate
PDRE	*14,993*	*102%*
LC/S	95,912	104%
DEGI	69,729	100%
IM	174,668	88%
PLRP TOTAL	355,302	

As shown by these results, the permanent demand reduction (PDRE) contributes a small fraction of the total demand response resource "enabled" by PLRP—about 4 percent of the total 355 MW resource. About 96 MW or 27 percent of the total PLRP demand reductions are due to load curtailment/shifting—technologies that allow customers to curtail or shift loads off peak when called. About 175 MW or 49 percent of the total are from customers that just received interval meters from PLRP, which are required to be able to participate in NYISO or other demand-response or load-management programs.

Lessons Learned and Transferability

NYSERDA's PLRP provides a good example of a program designed primarily to facilitate and enable customers to participate in demand response programs through installation of metering and control technologies. A unique feature of this program is that it explicitly includes a "path" for customers to install measures that achieve "permanent" demand reductions through improved energy efficiency. This illustrates the very close relationship between energy efficiency and peak demand reductions. In this case the program achieved nearly 15 MW of peak demand reduction.

With the growing interest and emphasis on demand response programs, which primarily call for customers to be able to curtail load upon market calls or price signals, this program demonstrates the value of promoting permanent demand reductions via energy efficiency in parallel or as part of integrated strategies for customers to reduce overall energy costs while helping utilities and system operators achieve important strategic reductions in peak demand.

National Grid 2004 Compressed Air Prescriptive Rebate Program
Organization: National Grid USA
Program type/sector: Industrial, Prescriptive Rebates
Technologies/end-uses: Compressed Air

Program Description

Under the "2004 Compressed Air Prescriptive Rebate Program," [14] National Grid USA offered financial incentives to industrial customers for a variety of technologies that improve the energy efficiency of compressed air systems. These technologies included:

- Variable speed compressors,
- Load/no load compressors,
- Variable displacement compressor,
- Cycling dryers, and
- Variable speed dryers.

Customer applications had to meet a set of criteria to qualify for prescriptive rebates. The criteria covered the compressor type, design function (primary supply only—not back-up units), control type, hours of operation, and various technical specifications for the unit and compressed air system within customers' facilities. For applications that didn't meet all the established criteria for prescriptive rebates, customers could apply for custom rebates. Incentive levels for the prescriptive measures for air compressors were given as a function of horsepower ($/hp). Customers completed an initial application that gave project information. Following submittal of the application, a National Grid Business Service Representative arranged an on-site inspection of the existing system or systems with the customer.

Evaluation Methods and Results

National Grid contracted with Demand Management Institute (DMI) to perform an impact evaluation of the 2004 Compressed Air Prescriptive Rebate Program. The scope of DMI's work was to provide:

- Annual energy savings,
- Summer and winter peak demand reduction, and
- "Realization" rates for the percentage of energy savings that occurs during on-peak hours (ratio of actual savings (ex post) during these times to predicted savings (ex ante)).

National Grid selected a sample of 20 prescriptive incentive applications to be evaluated by DMI and provided data on these selected sites.

[14] National Grid continues to offer prescriptive and custom financial incentives and technical assistance to its large commercial and industrial customers through "Energy Initiative"—an umbrella program that covers major electrical end-use categories, including lighting and controls, HVAC systems, motors, custom projects, compressed air and variable speed drives. This case study is based on an evaluation of the 2004 segment of the program targeting compressed air systems.

DMI developed the methodology for the evaluation of the specific types of compressed-air system end-use measures included in the applications. The methodology included review of project data submitted by the customer, on-site data collection of the equipment and systems, interviews with the customers, and application of algorithms and templates to estimate savings and other program impacts.

Two of the initial sites selected could not be evaluated due to equipment damage that made the equipment inoperable during the evaluation period. National Grid provided two replacement sites. DMI was unable to make contact with one of the other initial sites selected, which yielded a total of 19 sites included in the final sample set for the evaluation. Twelve of these sites had compressors only; three sites had dryers only; and four sites included both compressor and dryer projects. In the on-site interviews, DMI gathered data from the customer on current operations, hours of use (including operators' log sheets on the equipment) and the base or pre-retrofit conditions. Other on-site data collected included:

- spot-meter power and volt-amp measurements
- production throughput
- compressor operating speed (when applicable),
- pressure readings
- flow rates

Using metered data and customer-provided data DMI estimated annual energy savings, percentage of energy savings during on-peak periods, and peak demand reductions during both summer and winter on-peak periods. DMI developed specific data gathering and calculation methodologies for each of the different types of end-use measures evaluated in the study. These estimation methods included use of both diversity factors and coincidence factors for peak demand (kW) savings.

A major objective for this evaluation was to compare evaluated results (ex post) with the "tracking" analysis (ex ante) that was performed at the time when the initial application was submitted. These comparisons yielded "realization rates" for key variables. Gaining better understanding of realization rates allows National Grid to better estimate energy and demand savings from future applications for compressed air system and equipment retrofits.

The table below shows realization rates for evaluated compressors and dryers. These evaluation rates are for what was termed a "new" definition of "on-peak" demand periods (6 am to 10 pm M-F) and "summer peak" demand periods (3-5 pm M-F). These differ from "old" definitions of the same, which were 8 am – 9 pm M-F for on peak and 11 am – 3 pm M-F for summer-peak. The table also includes "existing" realization rates, which were the assumptions in place for estimating energy and demand impacts ex ante.

	Existing realization rates—used for both compressors and dryers	**Evaluated realization rate—compressors**	**Evaluated realization rate—dryers**
Summer kW	0.9	0.69	1.37
Winter kW	0.9	0.45	1.1
kWh savings	1.0	1.06	2.4
On-peak percentage savings	0.5	1.36	1.44
Operating hours	—	1.34	1.7

The results above suggest that realization rates for peak demand reductions (summer and winter) for compressors may be significantly less than previously assumed.

The evaluators also calculated average demand savings per horsepower (kW/hp) for compressors and average demand savings per volumetric flow rate (kW/cfm) for dryers. While useful for quick calculations, the evaluators urge caution in using such values as the demand (kW) savings are highly dependent on the load profile at each site. Since load profiles can vary greatly; so too will the potential demand savings. Given this caveat, the corresponding average values for these indicators are 0.152 kW savings/hp for compressors and 0.0043 kW savings/CFM for dryers. The table below gives values for types of measures.

	NGrid kW reduction (ex ante estimates)	**Evaluated Reduction (ex post estimates)**	**Sample Size**
Measure Types	kW savings/hp	kW savings/hp	
Load/no load compressor	0.102	0.0733	4
Variable displacement compressor	0.116	0.0424	1
Variable frequency drive compressor: 25 hp and greater	0.206	0.1908	11
Variable frequency drive compressor: 15-25 hp	0.207	N/A	0
Cycling dryer	0.00329	0.0044	6
Variable frequency drive	0.00329	0.00373	1

Finally, the evaluation estimated the total energy and peak demand impacts from the selected sites (not for the entire program).

Energy savings	
Tracking results (ex ante estimates)	741,585 kWh
Evaluation results (ex post estimates)	673,187 kWh
Coincident peak demand savings	
Summer kW tracking results	136.6 kW
Summer evaluated results	98.3 kW
Winter kW tracking results	136.6 kW
Winter evaluated results	75.7 kW

Lessons Learned and Transferability

The evaluators made the following recommendations based on their findings:

- The major source of discrepancy in evaluated results (ex post) versus original National Grid savings estimates (ex ante) is the difference in actual operating schedules from those initially reported. This suggests greater detail and accuracy in reporting operating hours by applicants, especially to account for such variables as processes that require air equipment to remain online overnight.
- More accurate loading profiles of existing equipment will increase tracking accuracy. Customers may benefit from working with equipment vendors to track actual compressed air demand over all operating hours to determine more accurate load profiles.
- Peak energy savings (kWh) should be derived from the actual schedule of operation.
- Peak demand (kW) reduction also should be derived from the actual schedule of operation. Facilities that operate on first shift will not see any demand reduction during the winter peak period.
- The gross savings factors for compressors used in the customer application process (ex ante estimates) were significantly higher than the savings factors measured and estimated for the evaluation (ex post estimates). Because of the small sample size, however, the realization rates found in the study should be used rather than adjusting the savings factors. Separate realization rates should be used for compressors and dryers as these were found to differ significantly.

The overall recommendation from the evaluation is to require applicants to complete a detailed chart or table with the daily hours of interest grouped together: on-peak, off-peak, summer and winter demand). The applicant would also then list estimates for the percentage of loading during each of these key periods.

This evaluation illustrates the importance of accurate on-site measurement and accounting of equipment operating schedules. Both energy and demand savings are clearly strong functions of these schedules; accurate estimation of such savings are thus highly dependent the accuracy of actual operating schedules of equipment. Compressed air systems—often considered a “utility” (like water or electricity) within a facility—offer significant energy and demand savings opportunities, but historically many facilities don’t record and maintain detailed operating logs of the equipment due to the nature of the systems as simply providing a utility to the process equipment.

National Grid Energy Initiative Program—Lighting
National Grid USA Service Company
Program type/sector: Rebates for energy-efficient retrofits/Commercial and industrial customers
Technologies/end-uses: Custom installations, HVAC, lighting, motors and variable speed drives.
Note: Lighting applications are profiled in this case study

Program Description

National Grid's "Energy Initiative Program" provides financial incentives (rebates) to commercial, industrial and government customers for energy-efficient retrofits of a wide range of end-use technologies, including lighting, HVAC, motors, drive systems and custom installations. Historically lighting measures have accounted for the largest share of total program savings. The types of indoor and outdoor lighting technology conversions or retrofits include:

- energy-efficient fluorescent systems
- energy-efficient ballasts
- compact fluorescent fixtures
- high intensity discharge (HID) fixtures
- high intensity fluorescent fixtures
- LED traffic signals
- energy-efficient exit signs

Customers complete and submit detailed applications to receive available financial incentives. Application materials include a detailed listing of eligible "efficiency improvement opportunities" for lighting systems and controls along with their corresponding incentives. Eligible opportunities must meet prescribed technical specifications and the proposed applications must meet minimum requirements for controlled wattage and potential savings reduction (minimum wattage reductions are prescribed in a lighting measures catalog).

Evaluation Methods and Results

National Grid's "Energy Initiative" offers incentives and related services across a broad spectrum of end-use technologies and applications. In evaluating this program, National Grid's approach has been to evaluate specific elements of the entire program according to specific end-uses and applications. This approach—especially for impact evaluations—allows program evaluators to tailor their methods to best suit the specific technologies being analyzed. Even under a single end-use category—such as lighting—there are two broad categories of applications—"prescriptive" and "custom." In this example we present two separate evaluations of lighting program elements: (1) the "2003 Energy Initiative Program: Lighting Impact Evaluation and (2) the "Custom Lighting Impact Study: 2004 Energy Initiative and Design 2000plus Programs." We include information on both evaluations as this illustrates the value of evaluations focused on a subset of target end-use technologies and applications. It well illustrates how program administrators often focus or isolate certain programs or program elements within a broad portfolio of programs or a comprehensive program for evaluation. It is not always practical, desirable or even possible within budget constraints to evaluate every program offered by a utility or other organization every year.

2003 Energy Initiative Program: Lighting Impact Evaluation

In 2004 National Grid contracted with RLW Analytics, Inc. to perform an impact evaluation of lighting measures—specifically for lighting fixtures only—under the Energy Initiative program. Lighting controls and other lighting system improvements not classified as "fixtures" were excluded from inclusion in this evaluation. Lighting fixtures constitute most of the total savings for lighting measures; in 2003 fixtures were estimated to account for about 95% of total lighting savings.

The primary goal of this evaluation was:

> …[T]o quanitify the actual energy and demand savings due to the installation of energy efficient lighting projects in the 2003 program year with ±10% precision at the 90% confidence level (RLW 2004b).

National Grid intends to use the results of the impact evaluation to achieve multiple objectives, which include:

- setting appropriate financial incentive levels for future program years,
- determining 2003 energy and demand savings accomplishments accurately, and
- demonstrating these savings accomplishments defensibly to regulators and other interested parties.

Specific objectives of the evaluation, along with data collection and estimation methodologies, were to (RLW 2004b):

- determine summer and winter diversity factors—derived from lighting logger loadshapes,
- determine connected kW realization rates—derived from differences in lighting counts and technologies between the observed quantity and type of lighting on-site and the appliance counts,
- determine the kWh realization rate and hours of use realization rate from the logger data, on-site data collected on the quantities and types of technologies observed, and customer application data (submitted to the program),
- calculate on-peak energy savings from logger data, and
- determine hours of use by major building type across all sample points.

RLW's evaluation methodology for achieving its goals included the following key steps:

- development of an efficient sampling plan to yield desired accuracy and confidence intervals,
- perform on-site assessments to verify measure quantities, installed technologies and hours of operation through time-of-use lighting loggers installed for 3-week periods, and

- perform engineering re-analyses and computations of kWh savings, connected kW savings, summer and winter diversified peak kW savings, and on-peak energy savings.

The total evaluated lighting energy savings were estimated to be 36,007 megawatt-hours (MWh), with an overall realization rate (ratio of ex post to ex ante estimates) of 101.4%. The error bound at the 90% confidence level is 2,557 MWh.

The table below presents the summary of Energy Initiative connected demand impacts. This table of results shows numerous adjustments that were made to the estimates to yield greater accuracy. Similar adjustments were also made for energy (MWh) savings.

	Connected Demand	
Parameter	kilowatt (kW)	% adjustment
Gross tracking savings (ex ante estimates)	7,364	—
Controls adjustment	0	—
Revised tracking savings	7,364	—
Documentation adjustment	62	0.8%
Technology adjustment	-9	-0.1%
Quantity (of measures) adjustment	145	2.0%
Connected demand reduction	7,562	2.7%
Cooling adjustment	1,003	13.6%
Summer coincidence adjustment	-2,076	-28.2%
Summer peak demand reduction	6,489	—
Heating adjustment	-209	-2.8%
Winter coincidence adjustment	-2,820	-38.3%
Winter peak demand reduction	4,533	—

The next table summarizes results for the primary evaluation goals.

Evaluation Result	**Evaluation Factors (%)**	**Relative Precision (%)**
Annual energy realization rate	101.4	±7.1
Energy on-peak percentage	69.3	±8.6
Hours of use realization rate	94.5	±7.6
Connected demand realization rate	102.7	±2.8
Summer diversity factor	85.8	±17.8
Winter diversity factor	59.9	±14.5

2004 Energy Initiative and Design 2000plus Programs: Custom Lighting Impact Study

In 2005 National Grid contracted with RLW Analytics, Inc. to quantify gross savings impacts—energy and demand—from "custom" (non-prescriptive) lighting measure installations in the Energy Initiative Program for retrofit applications and in the Design 2000plus Program for new construction applications. The primary objective of the study was to perform in-field (on-site) verification or re-estimation of electric energy (kWh) and demand (kW) savings estimates for a set of ten selected customer lighting projects through site-specific inspection, monitoring and analysis.

National Grid and RLW randomly selected ten custom lighting applications for the evaluation; one of these sites was divided into two separate applications due to characteristics of these applications. Thus a total of 11 applications were evaluated. The types of lighting measures in the selected set included lamp/ballast replacement, lighting controls (variable lighting levels), occupancy controls, daylight controls, dimming controls and combinations of these control and equipment technologies.

After gathering project information from data on file from customer applications and National Grid account information, RLW performed on-site, independent engineering assessment of the actual (as observed and monitored) annual energy, on-peak energy, diversified summer peak demand, and diversified winter peak demand associated with each project. The on-site data collection included:

- physical inspection and inventory of equipment,
- spot power measurements,
- interviews with facility personnel,
- observation of site operating conditions and equipment, and
- short-term metering of usage.

To collect necessary operating data for the evaluation, RLW used a variety of monitoring instrumentation and metering technologies, including time-of-use lighting loggers, current loggers, and power recorders.

RLW found that most of the projects trended at or below 100% realization for energy and demand savings. The table below presents summary findings. It is important to note that the nature of this evaluation was very different from that described above for the 2003 Energy Initiative Program; this evaluation examined a relatively small set of custom applications, not a broader set designed to yield overall program estimates.

National Grid Tracking Estimated Savings	
Energy savings (kWh/year)	2,082,524
On-peak energy use (%)	56
Peak coincident demand reduction:	
Summer (kW)	315
Winter (kW)	374
RLW Evaluated Savings	
Energy savings (kWh/year)	1,593,309
On-peak energy use (%)	53
Peak coincident demand reduction:	
Summer (kW)	266
Winter (kW)	238
Ratio of RLW/Tracking (ex post/ex ante)—non-weighted	
Energy savings (%)	77
On-peak energy use (%)	96
Peak coincident demand reduction:	
Summer (%)	85
Winter (%)	64

RLW cited a number of factors that led to over-estimation of the tracking (ex ante) savings, especially for energy savings (overall realization rate of 77%). These included “several significant errors in the estimation of tracking savings,” namely:

- missing fixtures at one-site,
- failure of a building energy simulation to accurately represent energy interaction between a skylight installation and lighting controls, as well as with HVAC and building shell,
- “grossly overstated” operating hours at one site (yielding a realization rate of just 12%),
- over-estimation of operating hours at another site, and
- overestimation of fixture counts at several sites due to poor record keeping by lighting contractors.

This last factor—overestimation of fixture counts due to poor record keeping—had a big impact on the total sample savings. This significantly affected four sites. If excluded, the sample yields a non-weighted realization rate of 101%. This suggests that the program enact more stringent review and documentation requirements for lighting contractors participating in the program.

Lessons Learned and Transferability

An over-arching lesson from these two separate evaluations of lighting measures implemented by the same program is that the methodology and design of impact evaluations will vary according to the goals established. In these cases, one impact evaluation sought to estimate overall program impacts for a specific category of measures (lighting fixtures) while the other evaluation sought to estimate impacts from a relatively small set of selected sites.

The former necessarily was broad in scope; the latter was much narrower, with greater emphasis on individual site measurement and analysis.

These cases both illustrate the need for some type of on-site measurement and monitoring for accurate estimation of peak demand impacts of installed energy efficiency measures, particularly as the equipment, systems and applications become more complex and customized to specific applications. In these examples, National Grid's realization rates for energy savings and connected demand savings (gross) were very accurate—close to 100%, with one exception. In the evaluation of custom installations, poor record-keeping by lighting contractors led to large errors in a small set of sites. If these problematic sites were eliminated, the overall realization rates would have similarly been close to 100%. This illustrates the importance of accurate data reporting and record keeping associated with applications from customers to participate in programs and receive program services.

While the tracking estimates of energy and connected demand savings proved to be very accurate, the realization rates for peak coincident demand reductions for both winter and summer peak periods generally were generally much lower than 100%—in the range of 60-85%. This suggests that accurate ex-ante estimation of these impacts is more difficult due to the unique operating characteristics of specific equipment and systems, especially when considering all the variables that affect performance of these technologies in any given application.

Evaluations such as these—with on-site measurement and monitoring of actual operating conditions—is critical to increase our understanding of and ability to predict peak demand impacts of energy efficiency measures more accurately.

APPENDIX E. CONTACT INFORMATION FOR DATABASES INCLUDED IN THIS REPORT

Database for Energy Efficiency Resources (DEER). California Energy Commission.
Contact via website: http://eega.cpuc.ca.gov/deer/

Deemed Savings Database, Version 9.0. New York State Energy Research and Development Authority.
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Deemed Savings, Installation & Efficiency Standards: Residential and Small Commercial Standard Offer Program, and Hard-to-Reach Standard Offer Program. Public Utility Commission of Texas.
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Conservation Resource Comments Database. Northwest Power and Conservation Council.
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website: http://www.nwcouncil.org/comments/default.asp

Technical Reference User Manual (TRM). Efficiency Vermont.
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