What's the NPV of R&D?
Benefit-Cost Assessment of a
Comprehensive Energy Research and Development Program

Ivin Rhyne, California Energy Commission, Sacramento, CA
Sandra Fromm, California Energy Commission, Sacramento, CA
Mitchell Rosenberg, KEMA, Inc., Burlington, MA

Abstract

This paper presents the methods and results of the first phase of the California Energy Commission's efforts to assess the benefits and costs of the Public Interest Energy Research (PIER) program. The PIER program was established by the California legislature in 1996. Through 2008, the program had funded some 1,700 research, development, and demonstration projects. The project portfolio is very broad, encompassing not only product development, but technologies to improve energy and water utility supply operations and basic research in support of energy and environmental legislation. This paper summarizes the CEC's first efforts to develop a general assessment methodology for the benefits associated with the PIER program and validate it using case studies. It presents the rationale for the general approach taken in the first phase, which consisted of case studies of four PIER projects designed principally to develop estimates of their benefits and costs. The paper then details the methods deployed and key results for two of the initial case studies. We conclude with a general appraisal of the results, identification of lessons learned for subsequent efforts.

Introduction

The California state legislature established the Public Interest Energy Research (PIER) program within the California Energy Commission (CEC) in 1996. The program's charter was to:

- Provide environmentally sound, safe, reliable, and affordable energy services and products;
- Support RD&D not adequately provided by competitive *or* regulated energy markets; and,
- Advance energy science and technology to the benefit of California's ratepayers.

Since that time, PIER has provided over $580 million in funding to some 1,700 projects. PIER's mandate and the program's interpretation of that mandate have been quite broad. The program supports not only the development and demonstration of energy-efficient products and services for end user markets, but many other kinds of projects as well. These include devices and operating methods that improve the efficiency and reliability of large energy and water systems such as the California transmission grid. PIER also commissions or conducts research to inform administrative and legislative initiatives related to energy efficiency. This last category of projects encompasses the provision of technical support for code changes as well as basic science and engineering research in support of much broader initiatives such as AB 32, California's comprehensive climate change legislation.

In late 2007, the CEC decided to develop and test an evaluation regime for the PIER program. Prior to that, the Commission had not conducted rigorous, independent assessment of the benefits generated by its projects. CEC and PIER program managers were motivated to undertake the evaluation effort by a number of factors, including:

- Legislative action to revise the program's goals to emphasize the following: *Develop and help bring to market energy technologies that provide increased environmental benefits, greater* *system reliability, and lower system cost*. (California SB1250) PIER believed that well-documented case studies would provide the most concrete evidence of progress towards this goal.

- Legislative action to increase the PIER program budget and range technologies to be addressed. In light of this change, CEC management felt it was important to demonstrate the value of the program, as well as its accountability and alignment with legislative intent.
- Given these changes, PIER program managers believed it was important to clarify and operationalize the concepts of program benefits and to quantify those benefits as one part of a framework to provide guidance to staff in project selection and management. The work presented here represents the first step major step in a longer-term process to formulate replicable project assessment practices and to incorporate those into program planning, management, and evaluation.

Planning for the First Phase of Evaluation

Selection of the Case Study Approach

As a first step in the overall program evaluation process, PIER commissioned a thorough review of the literature on evaluation and benefit-cost assessment of government-sponsored research and development programs. One key finding of this review is that work in this area splits into two general approaches:

- Case studies of individual *projects*; and
- Portfolio analysis, which attempts to assess the progress of a *program* consisting of many projects against the program's policy goals.

Case studies provide the flexibility needed to pursue and analyze data on individual projects in a manner that best represents their target markets and the nature of the benefits they produce. However, case studies are too expensive and time-consuming to cover more than a small portion of the projects in PIER's portfolio. Thus, they cannot by themselves convey a sense of the achievements of the program as a whole, or of its larger substantive divisions such as Energy Systems Integration or Renewable Energy. Studies at the portfolio level cannot support detailed estimates of the benefits of individual projects. Therefore, they must abstract from concrete benefits to more aggregated indicators of program success. For example, a recent evaluation of the New York State Energy Research and Development Authority's R&D programs collected and analyzed the ratings of a panel of experts regarding the performance of those programs along such dimensions as "Knowledge Creation" and "Realized and Potential Economic Benefits". (Heschong Mahone Group et al.) In some but not all cases, the evaluators had estimated the benefits of constituent projects, but these results could not be used consistently in a portfolio-wide analysis.

For this first phase of the evaluation, PIER opted to develop detailed case studies of project benefits. The rationale for this decision included the following points.

- The elapsed time and budget available did not accommodate a portfolio-level effort.
- PIER projects are very diverse in nature. It would have been difficult to develop applicable indicators for use across projects.
- Until this project, the benefits of individual projects had not been well-defined or quantified.
- The primary external audience for this project is legislators, who are naturally most concerned about concrete benefits such as energy savings or reduced emissions that the program produces for constituents.

Selection of Projects for Benefit-Cost Assessment

Selection Process. PIER management sought to achieve two key objectives in establishing the criteria and process for selecting projects for assessment.

- Select a set of projects distributed among the principal types identified in the portfolio.
  - *Products:* Projects aimed primarily at developing energy-efficient end-use products or service delivery tools.
  - *Systems:* Technologies to improve the performance of major energy or other resource delivery systems, such as the transmission grid or the Northern California reservoirs.
  - *Policy:* Research activities that provide insight to decision makers and other researchers seeking to understand energy related issues.
- Select projects sufficiently advanced to have generated economic and/or environmental benefits that could be quantified retrospectively or forecast with some degree of certainty.

KEMA sought nominations from PIER project managers to identify projects for benefit-cost assessment. Overall, project managers submitted nomination forms for 19 projects. The set of four projects chosen initially contained two product-oriented and two system-oriented efforts. Two additional product-oriented cases will be completed in September 2009.

Methods

Our literature review found that there were three key elements to be considered in developing methods for the benefit-cost assessments.

- ***Quantification of benefits.*** Researchers face a number of challenges in quantifying the benefits of R&D programs. These include:
  - *Diversity of benefit types.* Among the first four cases alone, potential benefits generated included: energy consumption savings, emission reductions, electric outages avoided, increased renewable electricity supply, increased availability of water during dry seasons, and enhanced flood control. Researchers need to be able to retrieve or develop data on the full range these potential project effects in order to bring them into the benefit cost assessment.
  - *Timing of benefits.* Given the length of time required for products to move through the early stages of market development or for new technologies to be integrated into large resource systems, evaluators of R&D programs must expect that most of the benefits they seek to quantify will accrue in the future. Thus, quantification of benefits will generally be accomplished through forecasts. It is best to use existing planning or forecasting models to develop these estimates to maintain consistency with previous work and to increase the likelihood that stakeholders will accept the results.
- ***Valuation of benefits and cost-effectiveness assessment.*** Again, to the extent possible, we attempted to use widely accepted methods and unit values in valuing benefits and characterizing project cost effectiveness. Thus, for cases involving efficient end-use products, we used the Total Resource Test procedures in the California *Standard Practices Manual* as well as current values for avoided energy costs to characterize cost effectiveness. For the improvements to the transmission and reservoir system, we used inputs from the California regulatory arena wherever possible.
- ***Attribution of benefits quantified to PIER activities.*** As in any evaluation, we needed to characterize and, if possible, quantify the value of the unique contributions that PIER activities made to the development of the technologies in question. Typically, this required the

development of two forecasts of benefits and costs: one representing the evaluation team's best estimate of benefits accrued over time with PIER activities in place and one without. Based on consideration of the nature of the projects studied, the prospective audiences for the benefit-cost assessment, data availability, schedule, and budget, the evaluation team elected to use the following two approaches to assess program attribution.

- *Historical Tracing*. Historic tracing (also known as the case study method) involves the careful reconstruction of events leading to the outcome of interest, for example, the launch of a product or the passage of legislation, to develop a 'weight of evidence' conclusion regarding the specific influence or role of the program in question on the outcome. Historical tracing relies on logical devices typically found in historical studies, journalism, and legal argument, including systematic examination of alternative hypotheses for consistency with known facts; systematic comparison of narratives provided by informants with different points of view or interests; analysis based on the order or precedence of narrative events.
- *Structured Expert Judging*. Expert judging processes, of which the Delphi approach is best known, have been used in evaluations of many energy R&D programs. (National Research Council 2007). Structured expert judgment studies assemble panels of individuals with close working knowledge of the technology, infrastructure systems, markets, and political environments addressed by a given R&D project to assess the likely outcomes of the project under two sets of assumptions: the program is in place and the program is not in place. Proper implementation of this method also requires a minimum elapsed time of 4 – 6 months to identify and recruit experts, prepare background briefings, and conduct two iterative rounds of judging.

Given schedule and resource constraints, the evaluation team decided to deploy expert judging only in cases where we anticipated that their judgments on the trajectory of technology development and acceptance would significantly affect the outcome of the overall benefit-cost analysis and where we could identify a relatively large number (15 – 20) of qualified observers from which to recruit the panel. These conditions held only in the case of the efficient external power sources.

Case Study Results

The following paragraphs summarize the methods and results two of the case studies completed to date. These cases illustrate the range of analytic challenges we encountered and the methods deployed to meet them. In addition to the case studies summarized below, we completed benefit-cost assessments on two other PIER projects:

- Demonstration of the ThermoSorber, a dual acting heat pump that supplies both hot and chilled water to industrial process applications
- Co-funding the development of INFORM, an integrated forecasting and decision support system used to help reservoir operators in the Sacramento River Valley better predict operating conditions and manage trade-offs among conflicting objectives.

External Power Supplies

Product Description. Power supplies are special circuits designed to reduce voltage delivered to electronic products from 120 volts to between 3 and 15 volts, convert it from AC to DC, and regulate the output to power a wide range of consumer electronics devices. In 2008, American consumers and business purchased over 550 million devices that use power supplies. (Darnel Group) Growth in saturation of power supplies has been very rapid. Recent studies estimate that more than six percent of national electricity consumption or 217 TWh per year passes through power supplies. (Ecos Consulting et al.) There are two basic design types for external power supplies: "linear" and "switching." Compared to linear designs, switching designs are smaller and much more energy efficient. Under Federal product standards that took effect in July 2008, all external power supplies (AC Adaptors) must use switching designs. The use of switching technology could lead to annual electricity savings of 550 GWh in California alone as conventional technology was displaced in the market.

PIER's Role and Project Costs. The PIER External Power Supply project was intended to support accelerated market acceptance of switched technology in external power supplies. A number of organizations had been active in promoting the technology to manufacturers prior to the initiation of PIER involvement in 2003. A number of activities, most notably the development of test procedures, were undertaken to promote this shift in market share. Ultimately, work carried out by the PIER project supported the incorporation of efficient external power supplies into California's Title 20 Appliance Efficiency Regulations by the CEC, which in turn supported the incorporation of similar but slightly more stringent specifications into federal product standards that took effect in 2008.

Estimates of Benefits and Costs. The estimation of the costs and benefits of PIER's support for the incorporation of efficient power supplies into California's Appliance Efficiency Standards proceeded in the following steps.

1. **Forecast the sales volume of devices covered by California and federal external power supply standards.** KEMA used market studies and proprietary data from 2003, 2005, and 2008 to develop trends in the sales volumes of key product categories covered by the external power supply standards through 2015. This analysis produced low, medium, and high growth scenarios which were used for sensitivity testing of the cost-effectiveness calculations.

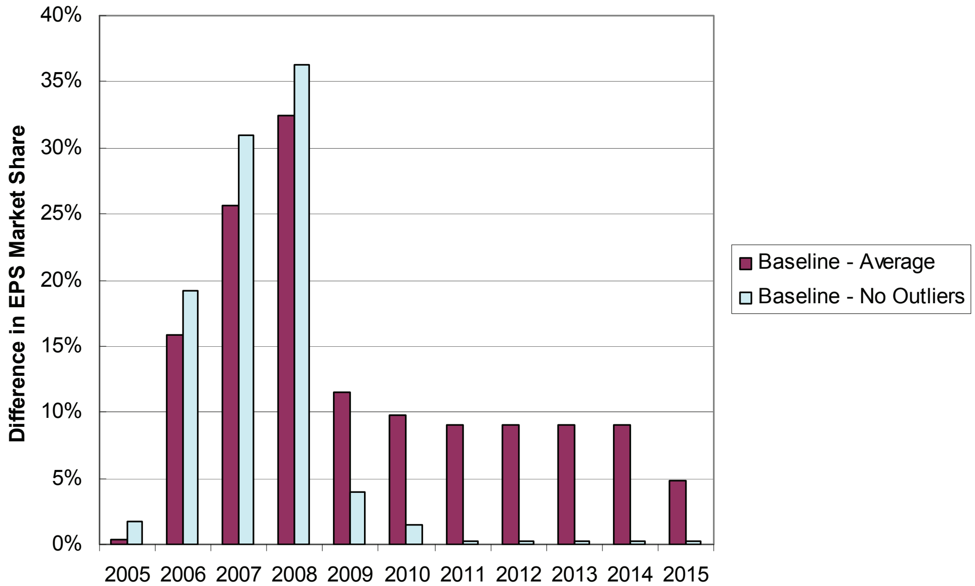
2. **Develop baseline estimates of the market share of energy-efficient power supplies.** KEMA used the results of a Delphi process involving a panel of six industry experts to develop baseline forecasts of the annual market share of efficient power supplies over the analysis period, that is: a forecast of what the market share would have been if California and federal power supply standards had not been promulgated in 2007 and 2008.

3. **Estimate the annual number of efficient power supplies sold that were attributable to PIER activities.** The Delphi panelists provided annual forecasts of the actual market share of efficient power supplies with the federal and state standards in place. Most believed that the market share would not reach 100 percent due to various compliance enforcement issues. We calculated a number of indicators of the central value for the annual market share estimates, including the simple average, the average without the high and low outliers, and the median. The latter two were nearly identical. We elected to use the average without outliers. This approach represented a compromise between incorporating the full spread of responses through a simple average and the year-to-year consistency of the median. Figure 1 shows the difference between the baseline and "actual" market shares for the United States,

estimated using the simple and truncated averages. As can be seen, the latter approach resulted in a lower estimate of the net effect of PIER activities.

We applied these differences in forecasted market share to the sales forecasts developed in Step 1 to calculate the annual number of net sales of efficient power supplies attributable to PIER activities.

Figure 1. Difference in Forecast Market Share of Efficient Power Supplies: Baseline v. Actual



4. **Estimate the stream of annual costs and benefits required for application of the Total Resource Cost test.** KEMA developed appropriate values for average savings per unit, average customer cost per unit, and average effective useful life from a wide variety of sources, including in-depth interviews with industry observers, technical studies, and market studies. These parameters were applied to the estimates of net units sold due to PIER intervention.

The key results of this analysis were as follows.

- Participants in the Delphi process stated that PIER's involvement accelerated the adoption of product standards for efficient power supplies by 1 to 10 years, with most registering assessments in the 2 – 3 year range.
- Using the annual baseline market share values, we estimated that PIER's efforts were associated with incremental sales of 917 million to 1.24 billion efficient units beyond what would have occurred in the absence of PIER efforts, over the 10-year analysis period. This is roughly 15 percent of the total number of covered devices forecasted to be sold over the analysis period.
- We estimated the net present value of these incremental unit sales at $983 million to $1.135 billion, depending on the input scenarios used.

Real Time Display Monitoring System (RTDMS)

Project Description. The Real Time Display Monitoring System is a set of computational and data visualization tools that enable the operators of California's transmission grid to use phasor measurements to identify potential reliability problems and to identify strategies to avoid them or mitigate their impact. Phasors are measurement devices that monitor local transmission system conditions at very short intervals – up to 20 times per second. The phasor/RTDMS system may also enhance the capability of the grid to manage large amounts of intermittent and unbalanced energy input from renewables, a major benefit that was not quantified in detail for this study. The currently deployed network of phasors covers much of the California transmission grid.

PIER's Role and Project Costs. The CEC has supported the development and testing of the elements of the RTDMS since 1999, with the first PIER contract issued in 2000. Some earlier prototyping of various elements of the system were supported by the U. S. Department of Energy's Transmission Reliability program. Over the past nine years, PIER has provided roughly $7 million to the project to support a wide variety of research and development of the various software and visualization tools required for real-time processing and display of phasor measurements.

Estimate of Benefits. KEMA estimated the value of the RTDMS by assessing its impact on the probability of outages and applying monetary values to the reduced experience of outages. This is not an academic exercise. On January 26, 2008 grid operators in at the California Independent System Operator (CAISO) used the RTDMS to detect undamped low-frequency oscillations in a portion of the grid which could have spread and caused significant instability in the system, including outages. The operators were able to take corrective action quickly to restore normal conditions and limit the spread of the oscillations.

The steps KEMA took to estimate the value of outages avoided, along with key intermediate results are as follows.

- **Set the potential outage boundaries**. The Western Electric Coordinating Council reliability control area, which encompasses California, has over 150,000 MW of peak load. California accounts for roughly one-third of that. Given the physical configuration of the system, instability at any point could lead to outages on the whole system.
- **Estimate outage probabilities and expected size of outages.** KEMA used published analyses of NERC outage data and data specific to WECC to estimate the expected value of an outage in terms of MWh of lost load. (Carreras et al.) Using the probability distribution derived from the NERC analysis, the expected outage size for California is 3,839 MWh and 10,645 MWh for WECC.
- **Estimate and apply outage costs per MWh**. KEMA used a variety of secondary sources on the value of lost load and the economic impacts of outages to estimate their social cost. The literature in this field presents a very wide range of estimates – from $2,000 to $40,000 per MWh of lost load. For purposes of this study, KEMA selected a value of $13,338 per MWh, based on and analysis of the impacts of the 2003 Northeast blackout. (LaCommare & Eto)
- **Establish baseline annual number of outages**. There have been few studies of aggregate outages on the WECC system that distinguish outages by geographic extent, load lost, and duration. The one study we could find estimated the average number of outages over 900 MW at 1.61 per year, based on analysis of several years of operating data. (Chen et al.) Since the data supporting this estimate were fairly thin, we used the estimate as a maximum in sensitivity analysis of project benefits.

- **Apply factor for reduction of probability of lost load**. RTDMS cannot be expected to eliminate outages entirely, but reduces their probability of occurrence in a given time period. It is not possible to estimate or forecast the extent to which RTDMS will reduce the probability of outages. KEMA therefore pursued a "sensitivity strategy" and estimated benefits from implementation of RTDMS assuming potential decreases in the probability of lost load of 10, 20, 30, 40, and 50 percent.

For the California region, estimated benefits over a 10-year period ranged from $26 to $338 million for California, and from $71 to $909 million for the entire WECC region (including California). These estimates do not include the value for a number of other hard-to-quantify benefits, such as mitigation of security threats associated with outages, relief of transmission system congestion, and increased capacity to manage injections of electricity wind and solar installations.

Attribution of Benefits to PIER Activities. KEMA assessed the extent to which potential benefits from the RTDMS project should be attributed to PIER activities using the results of structured in-depth interviews conducted with four individuals who were familiar with the full scope of phasor-oriented R&D in California and in other regions as well. These included a representative of the Center for Electric Reliability Technology Solutions (CERTS) which had cooperated in the project from the beginning, two representatives of the California Institute for Energy and the Environment, which took over joint management of the project in 2004, and the key project liaison from the California ISO. We asked the respondents to answer the following four questions.

1. If PIER had not funded the development and deployment of the Real Time Dynamics Monitoring System to the extent it actually did, do you think that other organizations would have supplied some or all of the required resources to the California ISO?
2. If PIER had not funded the development of the RTDMS to the extent it did, do you think the California ISO would have funded the research on its own through levies on market participants?
3. Did PIER provide technical assistance necessary to the success of the RTDMS research?
4. Considering the items we have discussed so far, what stage do you believe the development of the RTDMS would have attained as of January 2008 in the absence of PIER's involvement?

The consensus opinion of the respondents was that other organizations had neither the resources nor the mandate to contribute resources to RTDMS to the extent that PIER did and that, in the absence of PIER's involvement, development of the grid management capability described above – both in terms of technical tools and experience in using those tools – would have been delayed by at least seven years. Given that the benefits estimates were run over a ten-year forecast period, we applied this finding by attributing 70 percent of the outage avoidance benefits to PIER.

Table 1 shows the range of net benefits estimated, using the results of the sensitivity analysis.

Table 1. Results of Sensitivity Analysis on Estimated Net Benefits: PIER RTDMS Project

	Net Present Value of Benefits in 2008 $ Million					
	California			WECC		
	Average Annual Outages			Average Annual Outages		
Assumed reduction in outage probability	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
10%	$ 2.1	$ 28.3	$ 52.5	$ 17.5	$ 84.7	$ 151.9
20%	$ 11.2	$ 61.3	$ 111.3	$ 42.7	$ 176.8	$ 310.8
30%	$ 21.0	$ 105.9	$ 170.8	$ 67.2	$ 269.8	$ 470.4
40%	$ 30.1	$ 129.9	$ 229.6	$ 92.4	$ 360.9	$ 629.3

Overview of Results and Lessons Learned

Leverage of public investment. Table 2 summarizes the results of the four case studies. In terms of leveraging public investment, these projects were highly successful. PIER investment in the four projects reviewed totaled roughly $8.2 million, not including the costs of program staff time for project management. The benefits of introducing the project-supported technologies into their respective markets or resource delivery systems will exceed program costs by at least a factor of 10 under all plausible forecast scenarios and parameter values.

Table 2: Overview of Case Study Results

		Estimated Benefits	
Project/ PIER Investment	**Benefits Quantified**	**Physical Quantities** Range of Estimates	**Value of Benefits** Range of Estimates
Efficient External Power Supplies $577,082	Lifecycle Electricity savings	US: 27.5 – 37.3 TWh CA: 1.5 – 3.4 TWhr	TRC Net Benefit – 10 Years US: $955 mil. - $1.23 bil. CA: $67 mil. - $114 mil.
ThermoSorber $250,000	Electricity savings Natural gas savings	US: 24.4 GWh per year 4.6 MW 4.9 MTherms	TRC Net Benefit – 10 Years Only estimated low range $2.6 mil.
RTDMS $7,000,000	Electric service outages avoided, i.e. value of decreased probability of lost load	Expected outage size WECC: 10,645 MWh CA: 3,839 MWh	Net over 10-year period WECC: $17 mil. - $629 mil. CA: $2 mil - $230 mil.
INFORM $400,000	Incremental electric generation from reservoir dams in the Sacramento River system Incremental carry-over storage for dry seasons	700 GWh per year over the period 2006 – 2008 Varies by year modeled from 1,900 thousand acre feet (taf) *less* than baseline to 2,400 taf *more* than baseline	Net benefits over the period 2006 – 2008: $14 mil. - $82 mil. Varies by year. Recent costs of constructing and maintaining new capacity average ~ $3,700 per taf.

Of course, these case studies cannot be taken to represent the program as a whole. Program staff nominated the projects because they believed they had created demonstrable benefits or were likely to do so in the near future. Nonetheless, the case studies have provided a number of insights that will be valuable for program management.

Varied paths to creating public benefits. The case studies, considered in pairs by type – *product* and *system* – offer insights into the mechanisms by which R&D can generate social value.

- *Product support strategies.* In the case of external power supplies, PIER entered the market quite late in the product cycle, providing technical support for product standard revisions. However, participation of a technically-recognized body independent of the stakeholders was required at this point to develop a legitimate test method. Due to the size of the California market and the CEC's management of the standard revision process, this limited intervention proved to be strategically important in influencing national standards and therefore support for the change from international manufacturers. The enormity of the end-use pool affected assured significant net benefits, even if PIER's contribution to realization of those benefits was relatively limited and late in the process. In the case of the ThermoSorber, PIER provided funds for demonstration at a key juncture early in the product cycle when many inventions fail for lack of initial commercial interest. The potential market for the product is very small. However, the project shows good "upside" even with minimal sales due to the high unit savings potential and low unit costs. If the product does not take off at all, the agency and the taxpayers who support it have lost only a small investment.
- *Investments in resource systems.* The contrast between RTDMS and INFORM projects is also instructive. In the case of RTDMS, PIER took a lead role in funding the application of a relatively new technology within the day-to-day operations of the CAISO. PIER's long-term commitment to this effort has enabled CAISO to customize the application to its needs and has enabled grid operators whose decisions directly affect system reliability to become comfortable with using the RTDMS as a guide in daily control procedures. A number of respondents identified this steady commitment to the project as a major factor in its success. By contrast, funding for the INFORM project was suspended before early versions of the program could be refined for pilot testing. Reservoir managers have not had a chance to experience the benefits and challenges of using the system and remain non-committal at this point regarding the chances of INFORM's ultimate applicability. Therefore, the benefits for this project must be regarded as somewhat speculative.

Practical benefit-cost analysis lessons learned. Putting together a convincing case study requires many judgments along the way. It is often necessary to adjust lines of questioning and analysis as information comes in. Key practical lessons we took away from this set of case studies included.

- *Estimation of benefits.* It is important identify multiple potential methods with supporting data sources for estimating benefits early in the case study process, since it is likely that at least one of them will prove infeasible.
- *Attribution.* It is important to elicit answers to questions of attribution in ways that can be applied logically to the benefits estimates. One of the most useful approaches we found was to pose questions on net effects in terms of timing of various market events, such as the effective dates of product standards. This approach fit well with the forecast nature of the benefits estimates.

Value of early results to PIER. The results and insights provided by this evaluation have been exceptionally valuable in directing the California Energy Commission's (CEC) thinking about how best to proceed. The CEC specifically has drawn several insights into the future direction of its benefits assessment program:

- Collection of data at all points in the project is essential to valid post-assessment analysis. Current practices fall far short of analytical needs and will have to be revised as part of any systematic integration of benefits analysis
- The taxonomy of benefits (Environmental, Economic, and Security) is consistent with current DOE approaches and with legislatively mandated outcomes, and will therefore be used in future iterations of PIER program analysis
- A review of current literature suggests that further research into how best to quantify benefits may be of value. Specifically, the application of the correct metric for each type of benefit is crucial to both consistency of results and understandability to readers
- Exploration of hybrid approaches, including elements of project-level analysis with macro-level impact benefits may yield useful insights

From Case Studies to Portfolio-level Evaluation. As discussed earlier, the California Energy Commission and PIER program managers view the case studies as a first step in applying formal evaluation methods to assessing the program's accomplishments. Key questions to be addressed at the program portfolio level are as follows.

- **Is the PIER program as a whole cost-effective?** Based on our experience in conducting the case studies and review of the literature, we conclude that the best way to answer this question is to do more case studies of projects that the staff identifies as winners. Our rationale is that convincing quantification of the benefits or a given project and characterization of PIER's role in generating those benefits requires time-consuming and expensive research. Moreover, the diversity of PIER's projects in terms of the technologies they support, the market and regulatory environments in which they operate, and the strategies and tactics they use complicates the standardization of methods. On a positive note, the net benefits of the winners appear to be sufficient to justify the program. For example, even if the national benefits the external supply project were, in fact, 60 percent lower than our minimum estimate, they would still offset the total costs of the PIER program from its inception. So, if only 3 – 4 more significant winners, including the RTDMS project, are documented in the portfolio, it will be safe to conclude that the program as a whole is cost-effective.
- **How well is the PIER program doing in fulfilling its legislative mandates to develop environmentally sound, safe, reliable, and affordable energy services and products, support RD&D not adequately funded by the private sector, and advance energy science and technology to the benefit of California's ratepayers?** Addressing this question will likely require more of a portfolio-level assessment than PIER has so far pursued. A number of public sector RD&D programs have undertaken this type of research. Generally, they have sought to develop composite scoring methods that can be applied to all or a large portion of projects in the portfolio with relatively little research effort. NYSERDA conducted such a study, using a panel of outside experts to rate the portfolios of a RD&D program groups along the following dimensions: knowledge creation, knowledge dissemination, commercialization progress, realized and potential energy, economic, and environmental benefits, and "value versus cost". Independent evaluators prepared the information packets that supported the expert assessment, collected the expert scores, and analyzed and interpreted the results. (Heschong Mahone Group). The Advanced Technology Program (ATP) of the National Institute of Standards and Technology took the approach of using staff evaluators to develop composite scores for dozens of projects based on review of project records and interviews with program staff and grantees. (Ruegg) It is possible that these approaches provided value to the program sponsors. However, as outside readers, we found the ratings and sample project narratives too general to convey a strong sense of program accomplishments in relation to goals.

Ultimately, a useful evaluation effort is likely to require case study and portfolio-level components. It will also require strong processes to ensure that insights and results gained from program evaluation are taken into account in program planning and management. Based on our experience in conducting the case studies and our review of the RD&D evaluation literature, it is clear that trade-offs of time and resources will need to be made between these elements. Moreover, the right balance of these elements is likely to be unique to the client organization, given differences between programs in mandate, mission, and operating environment. Building on the results and practical knowledge gained from undertaking our first round of case study benefit-cost assessments, we believe PIER is well-positioned to address these next challenges.

References

Carreras, B. A., I. Dobson, E. Newman, and A. B. Poole. 2002. "Initial Evidence for Self-Organized Criticality in Electric Power System Blackouts". Power Systems and Communications Infrastructures for the Future. Biejing. 2002.

Chen, Jie, James S. Thorp, and Manu Parashar. 2001. "Analysis of Electric Power System Disturbance Data". *Proceedings of the 34th Hawaii International Conference on System Sciences - 2001.* Honolulu.

Ecos Consulting, Davis Energy Group, and Energy Solutions. *Codes and Standards Enhancement Initiative for PY2004: Title 20 Standards Development, Analysis of Standards Options for Single-Voltage External AC to DC Power Supplies*. Report prepared for Pacific Gas & Electric Company, May 3, 2004.

Heschong Mahone Group, Richard Ridge, GDS Associates. 2007. *Value-Cost Assessment of New York Energy $mart Research and Development Program: 2005.* Albany: New York State Energy Research and Development Authority.

LaCommare, Kristina Hamachi and Joseph Eto. 2004 *Understanding the Cost of Power Interruptions to U. S. Electricity Consumers.* Berkeley, CA: Ernest Orlando Lawrence Berkeley National Laboratory.

National Research Council. 2005. *Prospective Evaluation of Applied Energy Research and Development at DOE (Phase One): A First Look Forward*. Washington D.C.: National Academies Press.

Ruegg, Rosalie. 2006. *Bridging fro Project Case Study to Portfolio Analysis in a Public R&D Program: A Framework for Evaluation and Introduction to a Composite Performance Rating System.* Washington D.C.: US Department of Commerce, National Institute of Standards.