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The Cost and Performance of Utility Commercial Lighting Programs

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A Report from the Database on Energy Efficiency Programs (DEEP) Project

The Cost and Performance of Utility Commercial Lighting Programs

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Abstract

The objective of the Database on Energy Efficiency Programs (DEEP) is to document the measured cost and performance of utility-sponsored, energy-efficiency, DSM programs. Consistent documentation of DSM programs is a challenging goal because of problems with data consistency, evaluation methodologies, and data reporting formats that continue to limit the usefulness and comparability of individual program results. This first DEEP report investigates the results of 20 recent commercial lighting DSM programs. The report, unlike previous reports of its kind, compares the DSM definitions and methodologies that each utility uses to compute costs and energy savings and then makes adjustments to standardize reported program results. All 20 programs were judged cost-effective when compared to avoided costs in their local areas. At an average cost of 3.9¢/kWh, however, utility-sponsored energy efficiency programs are not "too cheap to meter". While it is generally agreed upon that utilities must take active measures to minimize the costs and rate impacts of DSM programs, we believe that these activities will be facilitated by industry adoption of standard definitions and reporting formats, so that the best program designs can be readily identified and adopted.

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Acronyms and Abbreviations

ACEEE	American Council for an Energy-Efficient Economy
BECo	Boston Edison Company
BHEC	Bangor Hydro-Electric Company
BPA	Bonneville Power Administration
CHG&E	Central Hudson Gas and Electric Corporation
C/I	Commercial and Industrial
C/I/A	Commercial, Industrial, and Agricultural
CMP	Central Maine Power Company
Con Edison	Consolidated Edison of New York, Inc.
DEEP	Database on Energy Efficiency Programs
DSM	Demand-Side Management
EI	Energy Initiative
EIA	Energy Information Administration
EPRI	Electric Power Research Institute
ESCO	Energy Service Company
GMP	Green Mountain Power Corporation
HID	High Intensity Discharge
HVAC	Heating, Ventilation, and Air Conditioning
IE	Iowa Electric Light and Power Company
IRP	Integrated Resource Planning
kWh	kilowatt-hour
LBL	Lawrence Berkeley Laboratory
NARUC	National Association of Regulatory Utility Commissioners
NEES	New England Electric System
NMPC	Niagara Mohawk Power Corporation
NORDAX	Northeast Region Demand-Side Management Data Exchange
NU	Northeast Utilities
NYSEG	New York State Electric and Gas Corporation
ORNL	Oak Ridge National Laboratory
PEPCO	Potomac Electric Power Company
PG&E	Pacific Gas and Electric Company
SAE	Statistically Adjusted Engineering Estimate
SCE	Southern California Edison Company
SCL	Seattle City Light
SDG&E	San Diego Gas and Electric Company
SMUD	Sacramento Municipal Utility District
TRC	Total Resource Cost Test

Executive Summary

In recent years, more and more utilities have begun offering demand-side management (DSM) programs, and more and more money has been spent on DSM. The Energy Information Agency (EIA) estimates that U.S. utilities spent more than $2.2 billion on DSM in 1992, up from $1.2 billion in 1991 (EIA 1993). Unprecedented growth in DSM spending has led some to become concerned that the results of DSM may be disappointing relative to the expenditures.[1] This concern regarding the economic value of DSM has been reinforced by recent work relating to the total cost and performance of utility activities to promote energy efficiency (Joskow and Marron 1992).[2]

Our study, the first in a series from the Database on Energy Efficiency Programs (DEEP), addresses concerns about the economic value of DSM activities by reporting on the total cost and measured performance of 20 utility-sponsored lighting efficiency programs in the commercial sector (Vine 1992).[3] The goal of the DEEP project is to compile and analyze the measured results of energy efficiency programs in a consistent and comprehensive fashion. The research concept for DEEP originated with previous work by the American Council for an Energy-Efficient Economy (Nadel 1990) and Lawrence Berkeley Laboratory (Krause et al. 1989), but has benefited enormously from the rapid maturation of the DSM industry, as evidenced by more utilities offering programs, many of which have now been evaluated formally. As a result, we are able to report on information previously missing from past analyses of utility DSM programs, such as customer cost contributions, and on program savings based on post-program evaluations rather than on unverified pre-program estimates.

We focus on the resource value that commercial lighting programs contribute to utilities' DSM portfolios.[4] Lighting is a major component of commercial electricity use

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[1] See Wirtshafter's (1992) comparison of the financial risks of DSM with the financial risks of nuclear power, the last new resource option aggressively pursued by the utility industry.

[2] Joskow and Marron examined 10 utility-sponsored DSM programs. They documented inconsistencies among utility accounting practices and expressed concern regarding utility reliance on pre-program savings estimates. They concluded that the evidence they collected "suggests that computations based on utility expectations could be underestimating the actual societal cost [of DSM programs] by a factor of two or more on average."

[3] We refer to these DSM programs broadly as commercial lighting programs. Although almost all programs in our sample were available to both commercial and industrial customers, and some programs were available to agricultural customers as well, most of the energy savings were attributable to commercial customers. We note in the text programs that offered non-lighting measures; and we included in our study only multi-technology programs for which lighting cost and performance data were separable from full-program data.

[4] There are, of course, other legitimate reasons for utility involvement in demand-side markets, such as equity and

(approximately 40%) and a significant component of industrial electricity use (approximately 10%) (EIA 1991). Investigations of the technical potential for efficiency improvements routinely conclude that 40% to 70% of current electricity consumption for lighting could be saved cost-effectively (see, for example, Atkinson et al. 1992, and EIA 1992). These and other estimates of lighting as a large, untapped, and cost-effective resource opportunity for energy efficiency have led U.S. utilities to promote customer adoption of energy-efficient lighting improvements as a core resource element of utility demand-side management activities.[5]

Twenty Commercial Lighting Programs

With substantial effort, we have developed a data set on the cost and performance of a significant fraction of utility spending on DSM. In aggregate, the 20 programs represent utility spending of approximately $190 million. Although not strictly comparable (because the spending for the programs we studied was spread over different years), $190 million represents about 15% of the $1.2 billion in nationwide utility spending on all DSM activities in 1991.[6]

Just as there is no such thing as a generic coal or advanced combined cycle plant, there is no such thing as a generic commercial lighting program. The commercial lighting programs we examine represent a broad cross-section of utility experience in promoting energy-efficient lighting in the commercial sector. They vary substantially in their life-cycle stages, delivery mechanisms, and technologies offered. These variations in design and implementation of DSM programs result from the evolution of energy-efficient lighting technologies in the commercial sector over time. Design variations are also the result of important differences in utilities': needs for new resources; avoided costs used to design programs; experiences with DSM programs and with local energy efficiency markets; as well as, in many cases, regulatory requirements.

customer service. From a resource planning perspective, however, energy efficiency programs are desirable only if they cost less than the alternatives available for meeting customer energy service needs. Accordingly, the primary measure of performance for commercial lighting programs is the total resource cost of the energy savings.

[5] The Electric Power Research Institute (EPRI) reports that, in 1992, 175 utilities offered some type of lighting efficiency program. The majority of these programs targeted commercial and industrial customers (EPRI 1993).

[6] Recall that utility spending on DSM includes spending on activities in addition to energy efficiency (such as load management and retention). Thus, although $190 million represents 15% of total DSM spending, it represents a much larger portion of utility spending on DSM activities that focus on energy efficiency.

Sixteen of our programs are full-scale, although eleven have been in full-scale operation for less than two and a half years. These programs accounted for an average of 25% of the utilities' budgets for energy efficiency programs. The four remaining programs are pilot programs.

Sixteen of our 20 commercial lighting programs offered rebates to customers, and four programs offered both the lighting equipment and installation at no cost to the customer. We refer to these latter programs, which require no out-of-pocket investment on the part of the customer, as "direct install" programs.[7] Among programs offering rebates, the rebate amount, type, and delivery mechanisms differed significantly. We expressed all rebates as fractions of the total measure cost, which the utility "bought down".

The mix of technologies offered by DSM programs is changing over time as new efficient technologies emerge and older efficient technologies become standard practice. The major categories of lighting equipment offered by the programs include compact fluorescent lamps, electronic ballasts, high-efficiency magnetic ballasts, reflector systems, T-8 efficient fluorescent lamps, T-12 efficient fluorescent lamps, lighting controls or occupancy sensors, and high intensity discharge (HID) lamps.

The program descriptions and results that we provide in this report should be considered "snapshots" in time. Many of these utilities have refined and improved their commercial lighting programs as they have matured. For the purposes of this report, we have treated our utility contacts as final authorities regarding the accuracy of program data. We acknowledge that the program data we use in this report may change in response to challenges emerging from a regulatory proceeding or through subsequent examination by the utilities or others.

Our experience in attempting to develop a consistent data set for this report demonstrates that the absence of standard terms to define DSM activity and the lack of consistent reporting formats are substantial, yet avoidable, liabilities for future DSM programs. Without standardized, consistent information, one cannot accurately compare DSM program experiences. Our work reduces considerably, but does not eliminate, these uncertainties for the 20 lighting programs in our sample. Industry adoption of a standard

[7] One rebate program provided a 100% rebate of installed costs; program participants, however, did have to make the initial cash outlay.

DSM terminology and a consistent format for reporting the results of DSM programs is important because accurate comparison of program experience is the most reliable basis for improving future programs.

The Total Resource Cost of Commercial Lighting Programs

The total resource cost for each of the 20 commercial lighting programs is presented in Figure EX-1. In this report, we consider the total resource cost of a program to be the total cost of the efficiency measures delivered through the program levelized over the lifetime energy savings achieved by the program, using a 5% real discount rate. Our findings directly address shortcomings that have been identified for previous estimates of total resource costs by (1) relying on post-program evaluations of energy savings rather than unverified pre-program estimates; and (2) accounting for the direct costs borne by both the utility and the participating customers, rather than only those costs borne by the utility.

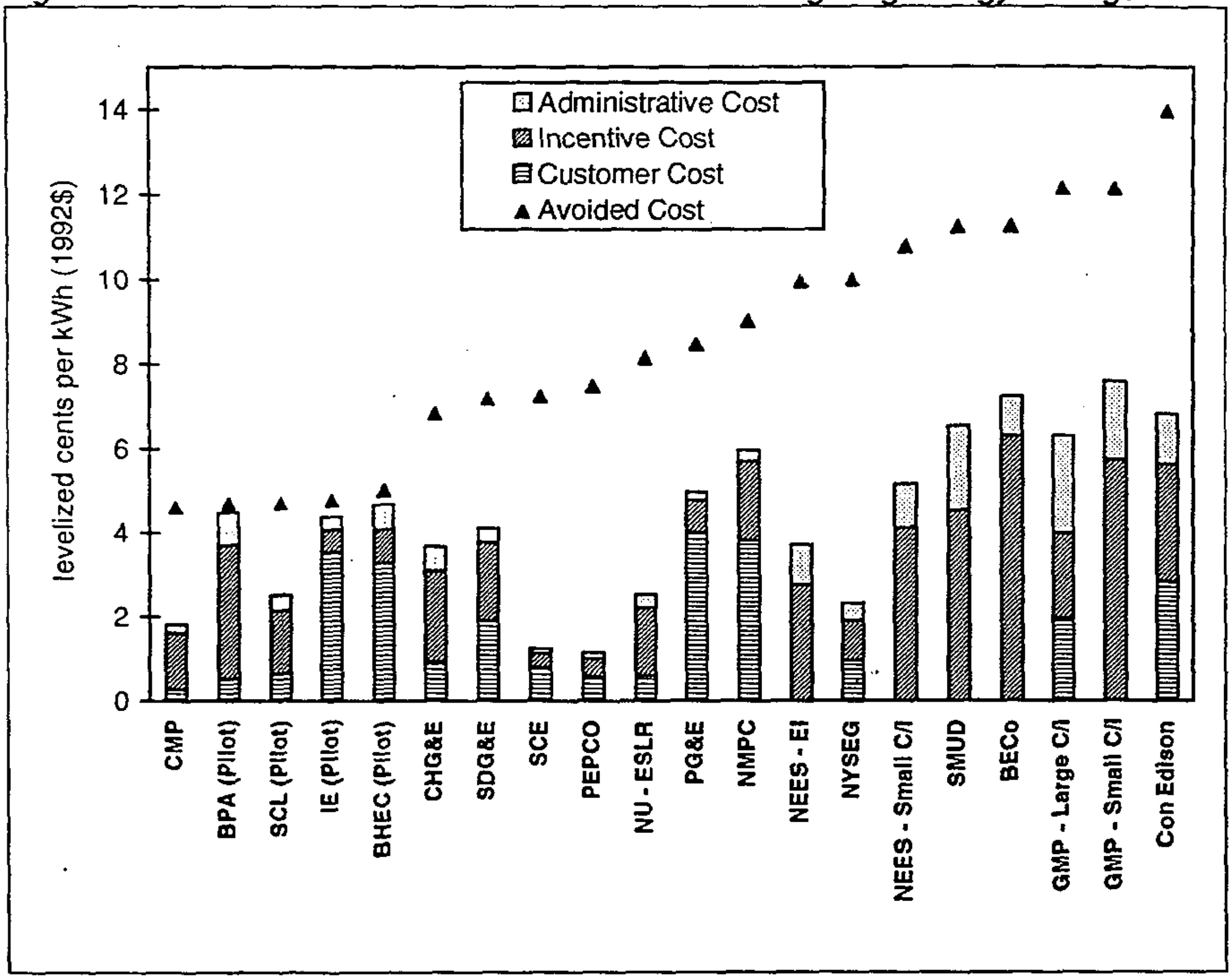
We find that the average cost of the 20 lighting programs is 4.4¢/kWh (in 1992 dollars), ranging from a low of 1.2¢/kWh to a high of 7.6¢/kWh. Weighted by energy savings, the average cost of the programs is 3.9¢/kWh. We find that utility administrative costs, weighted by energy savings, represent about 0.5¢/kWh or approximately 13% percent of the mean total resource costs of the programs. To the extent that the savings would not have occurred but for the utility's programs, these administrative costs are also an estimate of the size of the market barriers preventing their adoption in the absence of the utility program.

The ratio of the utility's avoided cost to the total resource cost for each of the 20 programs we examine is greater than 1.0, indicating that each is cost-effective.[8]

Many of the factors that result from program design choices can be systematically related to observed variations in program costs. For example, we find that the largest programs, as measured by total annual energy savings, have been substantially less expensive on a cost per kWh basis than the smallest programs. In addition, Figure EX-1 suggests that many aspects of program design and implementation are influenced by the avoided costs of the utilities; several of the more costly programs were developed by utilities facing very high avoided costs.

[8] *In standard DSM terminology, this ratio is referred to as the Total Resource Cost (TRC) Test.*

Figure EX-1. The Total Resource Cost of Commercial Lighting Energy Savings



Notes:

1) Levelized total resource costs and avoided costs are calculated at a 5% real discount rate.
2) Utility avoided costs are calculated by LBL from utility TRC test ratio estimates and utility estimates of program levelized costs, see Table 2-5.
3) Evaluation costs are not included in utility costs; based on the programs that do report these costs, we estimate that evaluation costs increase the utility component of total resource costs by about 3%. See the discussion of this issue in section 5.7.
4) Free riders' costs and savings are included in the calculation of levelized total resource costs. See the discussion of this issue in section 3.1.1.
5) We rely on utility post-program estimates of savings based on measured consumption data, and make no judgement on the accuracy of utility evaluation methods. For utilities who do not base post-program savings estimates on measured consumption data, we adjust their tracking database estimates of savings by the adjustment factor explained in section 5.2.

Other Measures of Program Performance

From a planning perspective, the total resource cost of DSM programs is probably the most important measure of program performance. However, the total resource cost is intimately related to other, often-cited measures of DSM program performance, such as participation rates, energy savings per participant, and the utility costs of DSM programs. Explicitly trading off these aspects of programs through various program designs is a primary challenge for utilities seeking cost-effective DSM. We identify current challenges to specifying participation rates, energy savings per participant, and utility costs consistently, and examine them in order to understand precisely what aspects of program performance they measure. We pay particular attention to specification of participation rates and distinguish their value for internal utility management from their value for other purposes such as cross-utility comparison.

Program participation rates are not defined consistently across utilities and, in any case, may not provide an appropriate basis for comparing programs. We found three general definitions of a program participant ("account number," "customer," and "rebates paid") as well as differences in definitions of eligible populations. Inconsistency in defining these terms can have a large effect on the calculation of participation rates (the ratio of participants to eligible population). Even when these problems of definition can be resolved, cross-utility comparisons are complicated by differences in program life-cycle stage and differences in the sizes of program budgets. Pilot programs or programs in their initial years of operation are often explicitly designed for limited participation; comparing these programs with mature programs is not appropriate. Even mature programs are sometimes limited in their performance by program budgets: we examined two programs that exhausted their budgets early in the program year and consequently had to turn participants away. Because of the factors that complicate annual participation rates, cumulative participation rates are probably more reliable indicators of performance. At the same time, the notion of a market saturation point for participation may be too limiting if the measures offered by the program are changing rapidly, which is likely because the energy efficient technologies offered by commercial lighting programs are rapidly improving and becoming less expensive.

The difficulty involved in measuring program participation consistently among DSM programs also complicates the examination of savings per participant as a measure of program performance. Moreover, for this measure to be a meaningful indicator of the "depth" of energy savings per participant, additional information is required on the cost-effective savings potential for each participant.

With regard to the utility costs of DSM, important inconsistencies in utility reporting of cost components limited our analyses to incentive costs versus all other costs (which we grouped under "administrative costs"). Because minimizing utility costs will reduce rate impacts, we examine the characteristics of programs with low utility costs (per kWh of savings). We find that utility costs are not systematically related to higher or lower total resource costs. This should come as no surprise because — except in the case of direct install programs — utility incentives cover only a portion of the total resource cost of energy efficiency. We then examine the impact of free riders on rate impacts because free riders cause the utility to incur costs that produce no net savings. We find that the rate impacts of free riders for our programs are significant — utility costs are 31% higher than they would have been without free riders. Consequently, we conclude that minimizing free riders (and taking credit for free drivers) should be an important program design strategy for minimizing rate impacts.

The Evolving Science of Measuring Energy Savings

Current practice in DSM program evaluation is evolving quickly. Five years ago we would have been hard pressed to find even a handful of programs with evaluations incorporating multiple measurement methods. We found it useful to distinguish between savings estimates that relied on tracking databases, which had been updated with substantial post-program information (such as hours of use, measures installed, etc.), and savings estimates based on analyses of measured consumption data (such as bills or end-use metering). Utilizing stringent selection criteria, we found almost a dozen programs with both tracking database and measured consumption savings estimates.

Surprisingly, we find little difference in the estimates of total resource cost based on the tracking databases and those based on measured consumption data. In part, this seems to be a result of different utility assumptions regarding the economic lifetimes of installed measures. Because measure lifetimes are a crucial component of energy savings and total resource cost estimates, we expect that current practice will begin to embrace medium- and long-term persistence studies in the near future. The short-term persistence studies in our sample of programs suggest that persistence in the first few years of measure operation is relatively high.

In our sample, ratios of measured consumption savings estimates to tracking database estimates ranged from 0.53 to 1.26, with a mean (weighted by energy savings) of 0.75. However, the diversity of methods used to calculate both types of savings estimates makes it difficult to draw conclusions about a reasonable range for this ratio. The particular methods one uses to calculate these savings estimates, and not just program design and implementation characteristics, profoundly affect the resulting ratio estimate.

Our review of free rider evaluation methods suggests that there is little consensus among utilities about the definition of a free rider. Although the absence of consensus is a secondary concern for the total resource cost of energy efficiency programs, free riders have important consequences for the impacts of programs on utility rates and thus ratepayers. We note, with some irony, that comparatively little attention has been devoted to measuring free-drivers and spillover effects, which both reduce total resource cost of energy efficiency and mitigate the rate impacts of these programs.

Concluding Thoughts

Our examination of the measured performance of 20 utility-sponsored commercial lighting programs has confirmed the cost-effectiveness of a significant portion of utility industry spending on DSM. Utility-sponsored energy efficiency programs, however, are not too cheap to meter. If future programs are to achieve their expected economic benefits, utilities must take active measures to minimize program costs and rate impacts. Our review suggests that ample room remains for program innovations to achieve these ends. We feel strongly that these improvements will be facilitated by industry adoption of standard definitions and reporting formats so that the best program designs can be readily identified and adapted.

Introduction

In recent years, more and more utilities have begun offering demand-side management (DSM) programs, and more and more money has been spent on DSM. The Energy Information Agency (EIA) estimates that U.S. utilities spent more than $2.2 billion on DSM in 1992, up from $1.2 billion in 1991 (EIA 1993). Unprecedented growth in DSM spending has led some to become concerned that the results of DSM may be disappointing relative to the expenditures.[1] This concern regarding the economic value of DSM has been reinforced by recent work relating to the total cost and performance of utility activities to promote energy efficiency (Joskow and Marron 1992).[2]

Our study, the first in a series from the Database on Energy Efficiency Programs (DEEP), addresses concerns about the economic value of DSM activities by reporting on the total cost and measured performance of 20 utility-sponsored lighting efficiency programs in the commercial sector (Vine 1992).[3] The goal of the DEEP project is to compile and analyze the measured results of energy efficiency programs in a consistent and comprehensive fashion. The research concept for DEEP originated with previous work by the American Council for an Energy-Efficient Economy (Nadel 1990) and Lawrence Berkeley Laboratory (Krause et al. 1989), but has benefited enormously from the rapid maturation of the DSM industry, as evidenced by more utilities offering programs, many of which have now been evaluated formally. As a result, we are able to report on information previously missing from past analyses of utility DSM programs, such as customer cost contributions, and on program savings based on post-program evaluations rather than on unverified pre-program estimates.

We focus on the resource value that commercial lighting programs contribute to utilities'

[1] See Wirtshafter's (1992) comparison of the financial risks of DSM with the financial risks of nuclear power, the last new resource option aggressively pursued by the utility industry.

[2] Joskow and Marron examined 12 utility-sponsored commercial lighting DSM programs. They documented inconsistencies among utility accounting practices and expressed concern regarding utility reliance on pre-program savings estimates. They concluded that the evidence they collected "suggests that computations based on utility expectations could be underestimating the actual societal cost [of DSM programs] by a factor of two or more on average."

[3] We refer to these DSM programs broadly as commercial lighting programs. Although almost all programs in our sample were available to both commercial and industrial customers, and some programs were available to agricultural customers as well, most of the energy savings were attributable to commercial customers. We note in the text programs that offered non-lighting measures, and we included in our study only multi-technology programs for which lighting cost and performance data were separable from full-program data.

DSM portfolios.[4] Lighting is a major component of commercial electricity use (approximately 40%) and a significant component of industrial electricity use (approximately 10%) (EIA 1991). Investigations of the technical potential for efficiency improvements routinely conclude that 40% to 70% of current electricity consumption for lighting could be saved cost-effectively (see, for example, Atkinson et al. 1992, and EIA 1992). These and other estimates of lighting as a large, untapped, and cost-effective resource opportunity for energy efficiency have led U.S. utilities to promote customer adoption of energy-efficient lighting improvements as a core resource element of utility demand-side management activities.[5]

This report is organized as follows. In Chapter 2, we describe the process of developing a consistent set of data on costs and energy savings for the 20 lighting efficiency programs in our sample. In addition, we summarize some of the primary difficulties in collecting data on DSM programs and suggest some ways of addressing this challenging problem. The programs are then summarized as a whole.[6] In Chapter 3, we report our major findings on the total resource cost and measured performance of the programs. We relate the differences in these costs to several of the variations in program design and implementation identified in Chapter 2. In Chapter 4, we use the basic findings on the total resource cost of the programs to provide a context for interpreting the significance of other often-cited measures of program performance, such as participation rates, energy savings per participant, and utility costs. We pay particular attention to the methodological issues associated with consistent specification of participation rates and distinguish the value of participation rates for internal utility management from their value for other purposes (e.g., cross-utility comparison). In Chapter 5, we review the evaluation methods used to estimate the energy savings, free riders and free drivers, and persistence of energy savings for the 20 lighting programs. We use this review to develop a taxonomy for classifying evaluation approaches that estimate energy savings.

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[4] There are, of course, other legitimate reasons for utility involvement in demand-side markets, such as equity and customer service. From a resource planning perspective, however, energy efficiency programs are desirable only to the extent that they cost less than the alternatives available for meeting customer energy service needs. Accordingly, the primary measure of performance for commercial lighting programs is the total resource cost of the energy savings.

[5] The Electric Power Research Institute (EPRI) reports that, in 1992, 175 utilities offered some type of lighting efficiency program. The majority of these programs target commercial and industrial customers (EPRI 1993).

[6] The programs are summarized individually in Appendix A. The DEEP data collection form is reproduced in Appendix B.

Twenty Commercial Lighting Programs

In this chapter, we describe the process of collecting data on the 20 commercial lighting programs in our sample, summarize some of the foremost difficulties in collecting data on DSM programs, and review important differences among the programs. In all cases, published utility evaluations and interviews with utility staff members were used to develop a consistent set of cost and savings data for the programs, so that all of our analyses are based on data verified by utility contacts. In several cases, utilities provided more accurate or more recent data than were available in the published sources of information on a DSM program. Utilities reviewed any adjustments we made to data provided by them (see primarily the discussions in Section 3.1 and Chapter 5). Individual descriptions of each program are provided in Appendix A.

We also review key features of the programs that provide the basis for explaining in subsequent chapters the differences in program performance and cost. We begin by establishing the role of each program in each utility's overall DSM portfolio. We then focus on specific features of the program design and implementation, including program maturity, eligible population, incentive type and structure, and lighting measures installed. We conclude our discussion by describing the economic context for the programs in terms of the average retail price of electricity for each utility and the avoided cost used in the design or regulatory approval phase of each program.

2.1 Developing Consistent Program Cost and Energy Savings Information

We began the data collection process by soliciting formal evaluation studies from candidate utilities and reviewing published articles and reports on the candidate programs. Using information from all published sources available to us, we completed as fully as possible a standardized DEEP data collection form based on those developed previously by the Northeast Region Demand-Side Management Data Exchange (NORDAX) and by Oak Ridge National Laboratory (Hirst and Sabo 1991). (The DEEP data collection form is reproduced in Appendix B.) We then established contact with one or more utility staff members familiar with the program and asked them to verify the information we had collected on their programs and to supply missing information.

Three objectives guided the process of selecting programs to study. First, we focused on commercial lighting programs because commercial lighting is perceived to be one of the largest and most cost-effective demand-side resources available to utilities. We considered three types of utility DSM programs: programs that offered only commercial lighting measures; programs whose savings were predominantly attributable to commercial lighting measures; and programs for which commercial lighting savings and costs were separable from the energy savings and costs associated with other efficient technologies offered by the program.

Second, because both lighting technologies and utility experience with demand-side programs are evolving rapidly, we sought cost and savings information for the most recent program year that it was available. We made this choice even though focusing on a single program year can complicate the attribution of costs incurred in a single year to the energy savings that occur in that same year, such as the costs of program evaluations, which almost by definition must take place in years subsequent to the energy savings. Similarly, pilot programs and programs in their first years of operation incur start-up costs that should be allocated, at least in part, to other program years. For all but six programs, five of which were terminated prior to 1991, data for the 1991 or 1992 program year were available.

Third, and most important, in order to estimate the total resource cost of energy efficiency, we considered only those commercial lighting programs for which we could obtain information on the total cost and performance of the program. For each program, we needed information on:

(1) post-program evaluation of energy savings;

(2) total cost of the program to the utility;

(3) total cost of the program to participating customers; and

(4) economic lifetimes of measures installed through the program.

These final requirements proved decisive in choosing the final set of programs analyzed in this report and restricted our focus to 20 out of the more than 50 programs we considered initially. Even for the 20 programs we chose, fewer than half formally reported all of the information required for our analysis. We frequently found that the information in the evaluation reports did not meet our needs for the following reasons:

(1) the methodology for calculating energy savings was not reported;

(2) energy savings were sometimes not identified as "net" or "gross"; and adjustments to energy savings (e.g. adjustments for free-ridership) were not always quantified or even described;

(3) the costs of the program to the utility, as well as to the program participants, were not reported;

(4) program costs, when reported, were not broken into subcategories other than incentives and administrative costs;

(5) participant costs, when reported, did not clearly indicate whether or not installation costs had been accounted for; and

(6) the number of program participants and the size of the eligible population were not reported.

Because essential data were lacking in evaluation reports, we sought information from other published material (e.g., utility filings with regulatory commissions) and contacted program managers and evaluators by telephone. In all cases, extensive discussions with utility staff members, over a period of weeks and sometimes months, were required to verify our interpretations of the utility-supplied information.

Frequently, reaching a contact at a utility and acquiring needed data was time-consuming and complicated. Utility staff members are busy, and they often did not have time to verify the information we had obtained from evaluation reports or to provide the missing pieces of information that we wanted. The hesitancy of utility contacts to assist us in our research was sometimes increased by our asking about a program year which would require them to retrieve archived data. Finally, particularly at larger utilities, we often had to contact several individuals within the organization in order to get answers to our questions regarding energy savings calculations, program costs, and eligible populations. Reaching so many staff members required additional effort and, because of the number of information sources, increased the potential for inconsistency in the data.

Even when we reached the person best able to verify our data and answer our questions, we were frequently confronted with inconsistencies — between data from the utility contact and from the evaluation reports, and even among the utility contacts themselves. The staff members sometimes informed us that the numbers we had taken from evaluation reports were no longer applicable. The most common explanations for this change were that program data had been updated, newer and better evaluation techniques were now being used on data from that program year, or that the numbers had been prepared for a regulatory filing and were not suited for our research purposes. After discovering data inconsistencies, we questioned the utility sources about which numbers to use; we were sometimes told to rely on a single report and other times were given new numbers altogether. On occasion, two contacts within a utility would disagree about the data we should use. In these cases, we asked the disagreeing parties to speak to each other and provide a joint recommendation.

For the purposes of this report, we have treated our utility contacts as final authorities regarding the accuracy of program data. We acknowledge that the program data that we use in this report may change in response to challenges emerging from a regulatory proceeding or through subsequent examination by the utilities or others. While our decision to regard utility staff members as having the last word may suggest some bias in our findings (no one wants to document or talk about programs that might be construed as having performed poorly), we believe that biases are likely to be small. For example, no utility program was dropped from consideration because of lack of cooperation in confirming or supplementing information for our project.

Although utility contacts were generally cooperative in providing information on their DSM activities, our work has made it very clear to us that future data collection and analysis would be facilitated by greater industry standardization of the terms and reporting formats for DSM program information. In some cases, we were able to resolve apparent inconsistencies in the data through discussion with utility program staff. For example, we were generally able to clarify the cost contributions of participating customers (see Chapter 3). In other cases, we were able to make adjustments to develop consistent cost and energy savings estimates (see Chapters 3 and 5). In several cases, however, the inconsistencies were impossible to resolve. As described in Chapter 4, for example, inconsistent definitions for key program parameters such as participation rates often preclude meaningful cross-utility comparisons of what would otherwise appear to be straightforward measures of program performance.

In order to improve the comparability of DSM programs across utilities, we agree with Hirst and Sabo (1991) that there is a real need to encourage consistency in the collection and reporting of data on DSM programs. There are encouraging signs in this direction: a few states (California, New Jersey, and New York) have developed measurement and evaluation protocols to encourage consistency among utilities as they collect, analyze, and report data. The Association of Demand-Side Management Professionals is also exploring options for encouraging similar guidelines among its members. The challenge to go beyond state boundaries to national guidelines and protocols will have to be faced by national organizations, such as the U.S. Department of Energy, the Electric Power Research Institute, and the National Association of Regulatory Utility Commissioners.

2.2 Summary of 20 Commercial Lighting Programs

The commercial lighting programs we examine represent a large cross-section of utility experiences with DSM. This section focuses on some of the differences in utility DSM experiences. Program design features and implementation experiences provide a basis for explaining the variations in program costs and energy savings described in subsequent chapters.

2.2.1 The Role of Commercial Lighting Programs in Utility DSM Portfolios

The commercial lighting programs we examine represent a significant portion of recent utility experience with DSM. In aggregate, the programs represent utility spending of approximately $190 million. Although not strictly comparable (because the spending for the programs we studied was spread over different years), $190 million represents about 15% of the $1.2 billion in nationwide utility spending on all DSM activities in 1991.[1] The programs we reviewed were often the single largest component of the sponsoring utility's DSM portfolio. Table 2-1 indicates the fraction of total utility DSM budgets represented by the 20 commercial lighting programs that we studied. For the 16 full-scale programs, commercial lighting accounted for an average of 25% of the utilities' budgets for energy efficiency programs. The significance of these programs within each utilities' DSM portfolio, and the large amount of money spent on them, highlights the importance of commercial lighting programs as a resource option for utilities. Consequently, understanding the cost of energy saved by the programs greatly contributes to our knowledge of DSM resource costs.

[1] Recall that utility spending on DSM includes spending on activities in addition to energy efficiency (such as load retention). Thus, although $190 million represents 15% of total DSM spending, it represents a much larger portion of utility spending on DSM activities that focus on energy efficiency.

Table 2-1. Fraction of Utility DSM Budgets Represented by Commercial Lighting Programs

Utility	Program Name	Year	Total Utility Expenditures on Electric Conservation Programs[1] ($Million)	Cost of Commercial Lighting Program to the Utility[2] ($Million)	Commercial Lighting Program Costs as a Percent of Total DSM Expenditures (%)
BECo	Small C/I Retrofit Program	1991	38.4	6.0	16
BHEC	Pilot Comm. Lighting Rebate Program	86-88	NA	0.2	NA
BPA	*Industrial Lighting Incentive Program*	86-87	221.1	0.9	0.4
CHG&E	Dollar $avers Rebate Program	90-91	4.9[3]	3.5	71
CMP	Comm. Lighting Retrofit Rebate Program	1992	16.4	1.4	9
Con Edison	C/I Efficient Lighting Program	1991	76.5	31.1	41
GMP	Large C/I Retrofit	1992	4.6	0.5	11
GMP	*Small C/I Retrofit*	1992	4.6	1.2	26
IE	Lighting Payback Plan	1990	NA	0.1	NA
NEES	Energy Initiative	1991	87.6	44.4	51
NEES	Small C&I	1991	87.6	12.9	15
NMPC	C/I Lighting Rebate Program	1991	42.8	20.1	47
NU	*Energy Saver Lighting Rebate*	1991	≈100	31.5	32
NYSEG	C/I Efficient Lighting Rebate Program	1991	23.5	5.5	23
PEPCO	Commercial Lighting Rebate Program	1990	20.9	1.6	8
PG&E	C/I/A Rebate: Direct Rebate Program	1992	118.0	12.0	10
SCE	Energy Management Hardware Rebate	1992	63.1	3.0	5
SCL	Commercial Incentives Pilot Program	1990	NA	3.1	NA
SDG&E	C/I Lighting Retrofit Program	1992	28.9	10.0	35
SMUD	Commercial Lamp Installation Program	1988	8.8	0.5	6

[1] These figures are taken from evaluation reports, annual DSM summaries, and other utility literature; all utility-related literature is cited in Appendix A. In some cases, the figure may include elements of a DSM budget that are not related to energy efficiency - such as load retention.

[2] For multi-technology programs, the cost indicated applies only to the lighting component of the program. Where available, the costs of program measurement and evaluation are included.

[3] This number represents DSM program costs incurred between 6/1/90 and 5/31/91.

2.2.2 Program Maturity

Program costs are generally thought to be related to program maturity. Pilot programs include start-up costs that make them appear more expensive although, in fact, start-up costs should be amortized over future program years. In addition, after the first few years during which utility program managers become familiar with what works for their target markets, program designs should stabilize and costs may decrease. At the same time, the amount of energy saved and a majority of program costs depend on what measures are offered by programs and what types of customers participate. Both of these, especially the measures offered (see 2.2.5 below), can change over a program's lifetime and complicate the process of determining how much program maturity influences program costs.

Table 2-2(a) shows the life-cycle stage, start date, and program year examined for each program. DSM programs are new undertakings for many utilities. Four of our commercial lighting programs are pilot programs, while 11 have been in full-scale operation for less than two and a half years. Several of the full-scale programs have been in operation for some time, although the utility has sometimes changed the program name. Most of the full-scale programs appear to have been preceded by pilots. As noted previously, we attempted to gather program information for the most recent program year that it was available.

2.2.3 Eligible and Target Populations

The cost of saved energy depends in large part on the characteristics of participating customers. For a given program budget, assuming that processing costs are not affected by rebate size (although, in fact, they can be), a program only available to large customers will tend to spread its costs per transaction over more energy savings, lowering the cost per unit of energy saved. Other factors, such as the size of incentives offered to customers who install DSM measures, can affect the amount of energy savings per customer and, even when normalized for customer size differences, may increase or decrease savings.

Table 2-2(a) shows the eligibility criteria for each program. Although all customers who meet the eligibility criteria may participate in a DSM program, utilities often target certain subgroups of customers through the structure of incentives and measures offered. Direct installation programs, for example, generally target smaller commercial customers. Insight into the effect of program design choices, such as who the target audience will be, can only be seen in program results. Hence, when we discuss targeting in subsequent chapters, we rely on savings per participant as a measure of actual population targeting.

Table 2-2(a). Overview of Twenty Commercial Lighting Programs

Utility	Life-Cycle Stage	Start Date	Program Year[1]	Specific Eligibility Criteria
BECo	Full-Scale	Late 1989	1991	Small non-residential customers with a peak demand < 150 kW
BHEC	Pilot	March 1986	86-88	All C/I customers
BPA	Pilot	Nov. 1985	86-87	All high-ceilinged C/I warehouse facilities in the Clark County area
CHG&E	Full-Scale	June 1990	90-91	All C/I/A[2], municipal, and not-for-profit customers
CMP	Full-Scale	1985	1992	All C/I/A customers
Con Edison	Full-Scale	Jan. 1990	1991	All C/I customers
GMP (Large C/I)	Full-Scale	Dec. 1991	1992	Large C/I customers w/ average monthly elec. use >12,500 kWh from Dec. through March[3]
GMP (Small C/I)	Full-Scale	May 1992	1992	Small C/I customers w/ average monthly elec. use >300 kWh but <12,500 kWh from Dec. through March
IE	Pilot	May 1990	1990	All C/I/A customers in Spirit Lake & Marshalltown service areas
NEES (EI)	Full-Scale	July 1989	1991	All C/I customers
NEES (Small C/I)	Full-Scale	June 1990	1991	Small C/I customers with monthly billing demand <50 kW or annual usage <150,000 kWh
NMPC	Full-Scale	Nov. 1989	1991	All C/I customers
NU	Full-Scale	March 1986	1991	All non-residential customers
NYSEG	Full-Scale	Jan. 1991	1991	All C/I customers
PEPCO	Full-Scale	March 1990	90-91	All commercial customers
PG&E	Full-Scale	Jan. 1990[4]	1992	All C/I/A customers
SCE	Full-Scale	1978	1992	All C/I/A customers
SCL	Pilot	July 1986	1990	All commercial customers
SDG&E	Full-Scale	Oct. 1990	1992	All C/I/A customers
SMUD	Full-Scale	Jan. 1986	1988	Small commercial customers with an energy demand ≤ 50 kW

[1] For each program, this is the program year examined in this report.

[2] Commercial/Industrial/Agricultural

[3] In addition, all C/I customers with five or more locations under the same corporate umbrella were eligible to participate.

[4] Although the current version of this program began in 1990, PG&E has operated some version of this C/I/A rebate program since the 1970s.

2.2.4 Incentives Offered

A distinguishing feature of the commercial lighting programs in our sample is that all utilities provide explicit incentives for program participation. The incentives distinguish these programs from information-only or audit-only programs, although providing information and audits was an important element of several programs. Table 2-2(b) shows the program type and incentive level during the program year examined for each of the 20 lighting programs. Incentives significantly raise the costs of programs to the utility (in contrast to information-only programs). While the level of incentive offered, as a fraction of total measure costs, should have little influence on the total resource costs of the energy savings, it may influence program participation rates. Aspects of this trade-off are explored in Chapters 3 and 4.

Sixteen of our 20 commercial lighting programs offered rebates to customers, and four programs offered both the lighting equipment and installation at no cost to the customer. We refer to these latter programs, which require no out-of-pocket investment on the part of the customer, as "direct install" programs.[2] Among programs offering rebates, the rebate amount, type, and delivery mechanisms differed significantly.

The most important difference among rebates is the way in which the amount of the rebates is calculated. We encountered three generic approaches:

(1) rebates based on an explicit fraction of either the direct capital or the capital and installation costs of the measures;

(2) rebates based on reducing the participant's payback time to some number of years; and

(3) rebates based solely on the value of either the energy or demand savings.

For example, Consolidated Edison of New York's (Con Edison) rebate covered 100% of the cost of efficiency measures and the customer paid the full cost of installation. In contrast, Green Mountain Power's (GMP) rebate for the Large C/I Program reduced the customer's payback time to two years. Often, approaches were used in combination. For example, Central Maine Power (CMP) paid 1¢/kWh saved, up to 80% of the equipment and installation cost.

[2] Although NEES's Energy Initiative program provided a 100% rebate of installed cost in 1991, the participant did have to make the initial cash outlay; hence, we have classified this program as a rebate program rather than direct install.

Table 2-2(b). Overview of Twenty Commercial Lighting Programs

Utility	Program Type	Incentive Level	Program Savings Examined in this Report
BECo	Direct Install[1]	100% of installed cost	Mostly lighting[2]
BHEC	Rebate	Up to 50% of installed cost[3] (≈20%, 86-88)	Lighting only
BPA	Rebate	Reduce payback to 1 yr (≈86% of installed cost in 86-87)	Lighting only
CHG&E	Rebate[4]	≈70% of installed cost in 90-91	Mostly lighting
CMP	Rebate	Up to 80% of installed cost (≈83% in 92)	Lighting only
Con Edison	Rebate	Up to 100% of equipment cost (≈100% in 91)	Lighting only
GMP (Lg C/I)	Audit, Rebate	Reduce payback to 2 yrs (≈55% in 92)	Lighting only[5]
GMP (Sm C/I)	Direct Install[6]	100% of installed cost	Mostly lighting
IE	Rebate	≈11% of installed cost in 90[7]	Lighting only
NEES (EI)	Audit, 100% Rebate[8]	100% of installed cost[9]	Lighting only[10]
NEES (Sm C/I)	Direct Install	100% of installed cost	Lighting only[11]
NMPC	Rebate	≈33% of installed cost in 91[12]	Lighting only
NU	Info, Audit, Rebate[13]	73% of installed cost in 91	Lighting only
NYSEG	Rebate	≈100% of equipment cost[14]	Lighting only
PEPCO	Rebate	≈42% of installed cost in 90-91	Lighting only
PG&E	Rebate	≈19% of installed cost in 92[15]	Lighting only[16]
SCE	Rebate[17]	Up to 30% of installed cost (≈35% in 92)	Lighting only[18]
SCL	Audit, Rebate	70% of installed cost	Mostly lighting[19]
SDG&E	Audit, Rebate	≈50% of installed cost (≈54% in 92)	Lighting only
SMUD	Direct Install	100% of installed cost	Lighting only

[1] "Direct Install" refers to programs in which the utility pays 100% of the installed cost of measures; no initial cash outlay is required from participant.

[2] "Mostly lighting" indicates a program for which almost all energy savings were attributable to lighting measures, although other technologies were offered. In our analysis, we include all costs and energy savings for these programs.

[3] Fixed rebate by measure, custom rebates of 1¢/kWh saved for up to 5 yrs, not to exceed 50% of installed cost

[4] The Dollar $avers program is offered concurrently with CHG&E's C/I Audit Program. Although audits aren't required in order to participate in the Dollar $avers program, some overlap exists.

[5] Other technologies were offered by the program. Lighting measures accounted for 58% of program savings.

[6] Custom measures were also available; for these, GMP reduced the payback period to one year. No custom measures were installed in 1992.

[7] DEEP estimate based on reported incentive and participant costs

[8] Although 100% of measure cost was ultimately paid by the utility, this program is not considered "Direct Install" because participants were required to make the initial capital outlay.

[9] Energy Initiative paid the full cost of all measures installed in 1991, but there were some measures for which cost-sharing would have been required had they been installed (particularly HVAC measures).

[10] Other technologies were offered by the program. Lighting measures accounted for 74% of program savings.

[11] Other technologies were offered by the program, but all recorded program savings came from lighting.

[12] DEEP estimate based on reported incentive and participant costs.

[13] Pre-installation inspection by the utility is required to verify the measure recommendations of trade allies.

[14] NYSEG's goal was to rebate the *incremental* cost of the equipment, but rebates during the evaluation period actually covered 100% of the *full* cost of the measure.

[15] DEEP estimate based on reported incentive and participant costs.

[16] Other technologies were offered by the program. Lighting measures accounted for 55% of program savings.

[17] Audits of participants in this program are provided through SCE's CIA Audits program.

[18] Other technologies were offered by the program. Lighting measures accounted for ≈31% of program savings.

[19] Although other technologies are offered by the program, and there was no information on breakdown of savings by measure for 1990, information from previous program years suggests that savings are largely attributable to lighting measures.

Rebates were either prespecified by the utility or determined on a case-by-case basis through "customized" programs. In the case of fixed rebates, utilities paid a predetermined amount for each unit of a lighting technology installed by program participants. Many programs featured long lists of lighting technologies with separate rebate amounts for each item. In the case of custom rebates, utilities determined a rebate amount for measures not appearing on a fixed rebate list. The custom rebates often involved new technologies that might appear on a fixed rebate list in future program years or technologies whose savings were highly dependent on specific applications. Generally, customers participating in custom rebate programs received incentives that were calculated based on reducing payback time or on the value of energy savings, capped at some fraction of total measure costs.

One of the difficulties in evaluating rebate levels in retrofit programs is establishing a baseline against which to measure costs. Total capital and installation costs seem most appropriate for situations in which working lighting systems are retired before the end of their useful lives. In some cases, where replacement is inevitable, incremental costs (for a more efficient system relative to what would otherwise be installed) may be more appropriate. Unfortunately, little information is available on the prevalence of premature equipment replacement (retrofit) versus normal equipment replacement. To our knowledge, all references to the capital and installation costs for our programs refer to the total rather than incremental costs of the measures.

We found it convenient to express the incentives offered by the utility as a reduction in the customer's direct, out-of-pocket costs for measure adoption. Thus, we express the incentive amount as a fraction of total measure costs (including both capital and installation costs), which the utility, in effect, "buys down".

2.2.5 Lighting Measures

Energy-efficient lighting resources consist of many technologies and operational practices. The combinations of technologies offered can vary dramatically from program to program and — more importantly — from year to year, as technologies mature and new ones enter the market place.[3] Table 2-3 summarizes the major lighting technologies offered by our programs in the years considered in this report. We also list non-lighting measures offered as part of more comprehensive programs targeting commercial customers.

[3] The changing nature of the measures offered by lighting programs affects DSM program saturation. See Chapter 4.

Table 2-3. Technology Breakdown for Commercial Lighting Programs

Utility	CF	EB	MB	RS	T-8	T-12	LC	HID	O/M	Other Lighting Measures	Other Measure Categories
	Lighting Measures[1]										
BECo	✔	✔		✔	✔	✔	✔	✔		Halogen lamps	HVAC, Hot Water, Motors, Building Envelope, Refrigeration, Cooking
BHEC	✔	✔				✔	✔	✔		Current limiter	No
BPA								✔		No	No
CHG&E	✔	✔	✔	✔	✔	✔	✔	✔		Current limiters	HVAC, Motors
CMP	✔	✔		✔	✔	✔	✔	✔		Efficient incandescent	No
Con Edison	✔	✔	✔	✔	✔	✔	✔			No	No
GMP (Lg C/I)	✔	✔	✔	✔	✔	✔	✔	✔		No	HVAC, Hot Water, Motors, Demand Control, Building Envelope, Refrigeration, Cooking, Industrial Process
GMP (Sm C/I)	✔	✔		✔	✔	✔	✔	✔		Halogen lamps, pin socket replacement	HVAC, Hot Water, Motors, Refrigeration, Industrial Process
IE	✔	✔	✔		✔	✔				No	No
NEES (EI)	✔	✔	✔	✔	✔	✔	✔	✔		Efficient incandescents	HVAC, Hot Water, Motors, Demand Control, Building Envelope, Refrigeration, Process, Custom
NEES (Sm C/I)	✔	✔	✔	✔	✔	✔	✔	✔		No	HVAC, Hot Water
NMPC	✔	✔		✔	✔	✔	✔	✔		Hybrid ballasts	No
NU (ESLR)	✔	✔	✔	✔	✔	✔	✔	✔		Exit sign retrofits	No
NYSEG	✔	✔		✔	✔	✔	✔	✔		Reflective ceiling, hybrid ballasts	No
PEPCO	✔	✔	✔	✔	✔	✔	✔	✔		Exit sign retrofits	No
PG&E	✔	✔		✔	✔	✔	✔	✔		Halogen infrared lamps, photocell, current limiter	HVAC, Motors, Building Envelope, Refrigeration, Agriculture, Cooking
SCE	✔	✔			✔	✔	✔	✔		Halogen lamps, current limiters, exit sign retrofits, efficient incandescents, hybrid ballasts	HVAC, Hot Water, Motors, Building Envelope, Refrigeration, Custom
SCL		✔	✔			✔	✔	✔	✔	Delamping	HVAC, Hot Water, Motors, Building Envelope, Refrigeration, Demand Control
SDG&E		✔		✔	✔	✔				Hybrid ballasts, custom	No
SMUD						✔[2]				No	No

[1] CF: Compact Fluorescent Lamps; EB: Electronic Ballasts; MB: High Efficiency Magnetic Ballasts; RS: Reflector Systems; T-8: T-8 Efficient Fluorescent Lamps; T-12: T-12 Efficient Fluorescent Lamps; LC: Lighting Controls or Occupancy Sensors; HID: High Intensity Discharge Lamps

[2] A few other technologies were offered, but fluorescent lamps accounted for 99% of program savings.

The major categories of lighting equipment offered by the programs include: compact fluorescent lamps, electronic ballasts, high-efficiency magnetic ballasts, reflector systems, T-8 efficient fluorescent lamps, T-12 efficient fluorescent lamps, lighting controls or occupancy sensors, and high intensity discharge (HID) lamps.

Three features stand out in Table 2-3. First, all of the programs but two (Bonneville Power Administration (BPA) and Sacramento Municipal Utility District (SMUD)) offered a wide range of lighting measures, in contrast to a few years ago when many lighting programs offered only a single lighting technology, such as compact fluorescent lamps or watt-miser fluorescent tubes (see Krause et al. 1989). Second, electronic ballasts are now routinely offered, while energy-efficient magnetic ballasts are no longer promoted in most of these programs. This change results directly from federal standards that, in 1988, mandated that all ballast manufacturers produce only high efficiency magnetic ballasts.[4] Third, lighting controls, which are more difficult to evaluate from an energy savings perspective, are now commonly available in most commercial lighting programs.

It is important to emphasize that, in contrast to the diversity of measures *offered* by the programs, the measures actually *installed* may be limited to a few categories. Most often, retrofits involve replacement of standard incandescent and fluorescent lamps with energy-efficient fluorescent products. Unfortunately, we have not been able to collect data systematically on the distribution of energy-efficient technologies that underlie the energy savings from each program.

2.2.6 Retail Rates and Avoided Costs

Many of the trade-offs inherent in the program design decisions described above reflect the economic environment in which the programs are developed and implemented. For example, the retail price for electricity determines the cost-effectiveness of efficiency measures for program participants. We noted earlier that many incentives or rebates are set according to the cost-effectiveness of measures for participants. More importantly, the cost-effectiveness of programs using either the Total Resource Cost Test (TRC) or the Non-Participant Test depends heavily on the avoided cost faced by the utility.[5] Other things being equal, a capacity-constrained utility with high avoided costs will be able to cost-

[4] See National Appliance Energy Conservation Amendments of 1988.

[5] See Krause and Eto (1988) for definitions and discussions of these cost-benefit tests.

effectively pursue much more expensive energy savings than a utility with low avoided costs. Our discussions in Chapter 3 suggest that high avoided costs were an important part of the explanation for some of the more expensive programs that we studied.

Table 2-4 summarizes retail rate information by customer class; rates are expressed as a percentage of the average rate for the utility as a whole for the program years that we examined. Table 2-4 also summarizes avoided cost information developed specifically for the programs and program years examined. These costs were derived primarily from utility supplied information on the cost-effectiveness of the programs; utilities typically developed this information for filings seeking regulatory approval for the programs. The costs, therefore, represent an average developed through a weighting of the expected load shape impacts of the lighting programs and the time-differentiated energy and capacity avoided costs. It is important to bear in mind that, while these costs represent an accurate assessment of the projected value of the programs at the time the programs were approved, the costs do not represent the utilities' actual avoided costs, because these are likely to change over time.

2.3 Summary

With considerable effort, we developed a data set on the cost and performance of a significant fraction of utility DSM spending. Altogether, the 20 programs in our sample represent utility spending of approximately $190 million. Although not strictly comparable (because spending for the 20 programs was spread over different years), $190 million represents approximately 15% of the $1.2 billion in nationwide utility spending on all DSM activities in 1991.

Just as there is no such thing as a generic coal or advanced combined cycle plant, there is no such thing as a generic commercial lighting program. The commercial lighting programs we examine represent a broad cross-section of utility experience in promoting energy-efficient lighting in the commercial sector. They vary substantially in their life-cycle stages, delivery mechanisms, and technologies offered. These variations in design and implementation of DSM programs result from the evolution of energy-efficient lighting

Table 2-4. Retail Rates and Avoided Costs

Utility	Year	Average Price of Electricity Across All Sectors (92$) (¢/kWh)[1]	Price of Commercial Electricity as Percent of Average Price of Electricity	Price of Industrial Electricity as Percent of Average Price of Electricity	Levelized Avoided Cost at Time the Lighting Program Was Developed (92$) (¢/kWh)[2]	Program-Specific Avoided Cost as Percent of Average Price of Electricity
BECo	1991	9.6¢	96%	85%	11.3¢	118%
BHEC	1988	8.2¢	114%	79%	5.0¢	61%
BPA	1988	NA	NA	NA	4.7¢	NA
CHG&E	1991	8.1¢	104%	71%	6.8¢	84%
CMP	1992	8.8¢	103%	74%	4.6¢	52%
Con Edison	1991	13.1¢	94%	92%	14.0¢	107%
GMP (Lg C/I)	1992	7.3¢	107%	80%	12.1¢	165%
GMP (Sm C/I)	1992	7.3¢	107%	80%	12.1¢	166%
IE	1990	8.0¢	102%	63%	4.8¢	60%
NEES (EI)[3]	1991	9.2¢	94%	101%	10.0¢	109%
NEES (Sm C/I)	1991	9.2¢	94%	101%	10.8¢	117%
NMPC	1991	8.1¢	114%	62%	9.0¢	111%
NU[4]	1991	10.3¢	100%	84%	8.1¢	78%
NYSEG	1991	9.6¢	99%	75%	10.0¢	104%
PEPCO	1991	6.6¢	103%	84%	7.5¢	114%
PG&E	1992	10.3¢	105%	71%	8.5¢	82%
SCE	1992	10.5¢	108%	76%	7.2¢	68%
SCL	1990	3.4¢	98%	87%	4.7¢	139%
SDG&E	1992	9.3¢	97%	79%	7.2¢	77%
SMUD	1988	8.7¢	102%	81%	11.2¢	129%
Average		**8.8¢**	**102%**	**79%**	**8.5¢**	**102%**

[1] For each utility, the average electricity prices in this table pertain to the program year examined in this report. LBL estimates of average electricity prices are based on data contained in EIA's "Financial Statistics" documents, which are cited in the general references.

[2] LBL estimates of avoided cost are derived from utility calculations of program cost-effectiveness and are based on a weighted average of energy and capacity savings.

[3] Because NEES is composed of Massachusetts Electric Company, Narragansett Electric Company, and New England Power Company, the average price of electricity across all sectors is calculated based on average prices for all three utilities.

[4] Because NU is composed of Connecticut Light & Power Company, Western Massachusetts Electric Company, and Public Service of New Hampshire, the average price of electricity across all sectors is calculated based on average prices for all three utilities.

technologies in the commercial sector over time. Design variations are also the result of important differences in utilities': needs for new resources; avoided costs used to design programs; experiences with DSM programs and with local energy efficiency markets; as well as, in many cases, regulatory requirements.

The program descriptions and results that we provide in this report should be considered "snapshots" in time. Many of these utilities have refined and improved their commercial lighting programs as they have matured. For the purposes of this report, we have treated our utility contacts as final authorities regarding the accuracy of program data. We acknowledge that the program data we use in this report may change in response to challenges emerging from a regulatory proceeding or through subsequent examination by the utilities or others.

Our experience in attempting to develop a consistent data set for this report demonstrates that the absence of standard terms to define DSM activity and the lack of consistent reporting formats are substantial, yet avoidable, liabilities for future DSM programs. Without standardized, consistent information, one cannot accurately compare DSM program experiences. Our work reduces considerably, but does not eliminate, these uncertainties for the 20 lighting programs in our sample. Industry adoption of a standard DSM terminology and a consistent format for reporting the results of DSM programs is important because accurate comparison of program experience is the most reliable basis for improving future programs.

The Cost and Performance of Commercial Lighting Programs

This chapter uses the information developed for the 20 commercial lighting programs described in Chapter 2 to determine the total resource cost of the energy saved by the programs. Our findings directly address shortcomings that have been identified for previous estimates of total resource costs by (1) relying on post-program evaluations of energy savings rather than unverified pre-program estimates and (2) accounting for the direct costs borne by both the utility and the participating customer rather than only those costs borne by the utility.

We calculate the total resource costs for the 20 lighting programs by levelizing the total cost of the energy savings over lifetime energy savings. The information required for this calculation includes annual energy savings, the costs incurred by the utility as well as the program participants, the economic lifetimes of installed measures, and a discount rate.[1] We also discuss the method we adopted for treating the savings and costs associated with free riders.

We then present our findings and comment on the cost-effectiveness of the 20 programs, using the avoided costs developed in Chapter 2. We also examine how program design features appear to influence the total resource costs of the programs. In a final section, we quantify the minor influence of free riders on the total resource cost of energy efficiency.

3.1 Estimating the Total Resource Cost of Commercial Lighting Programs

The total resource cost of energy efficiency acquired through a utility-sponsored commercial lighting program is a function of: (1) the annual energy savings of program participants; (2) the total cost of the energy efficiency program, including incentives paid by the utility to participating customers, administrative costs to the utility, and the cost of the program to participating customers; (3) the economic lifetimes of installed measures; and (4) a discount rate that specifies the time value of money. This section describes the development of this information for the 20 utility programs considered in this report.

[1] Because the practice of program evaluation is evolving rapidly, we address separately (in Chapter 5) the savings evaluation methods employed by the utilities and the influence of alternative uses of these methods on the results presented in this chapter.

3.1.1 Annual Energy Savings

The energy saved by a commercial lighting DSM program cannot be observed directly because it is the difference between (a) an estimate of the energy use that would have occurred in the absence of participation in the utility's program and (b) the actual energy use as a result of participation. The use of efficient lighting equipment affects the difference in energy use before and after participation; however, the change in energy use is also affected by changes in the lighting amenities provided (e.g., changes in lighting operating hours, areas lit, and lumens of light delivered) as well as by interactions among lighting and non-lighting energy uses (most notably, HVAC energy use). Before post-program evaluation studies were done, estimates of the net energy savings realized by utility DSM programs were, of necessity, based on unverified planning assumptions.

All energy savings estimates presented in this chapter are based on post-program evaluations and were either taken from an evaluation report and then verified by the utility or received directly from a utility contact. Relying on post-program evaluation information greatly increases our confidence in several aspects of the energy savings calculation. At a minimum, the actual number of program participants or installations has been verified; and for several programs, limited end-use metering and on-site inspections further increase the accuracy of the savings calculation. We refer to post-program energy savings developed in this fashion as *tracking database* estimates. In addition, many of the programs have used quasi-experimental program evaluation designs to introduce billing and other measured consumption data into the estimation of post-program and baseline energy use. We refer to post-program energy savings developed in this fashion as ***measured consumption*** estimates. These distinctions are discussed in detail in Chapter 5.[2]

To ensure consistency in the specification of energy savings across programs, we subjected the energy savings reported by the utilities to a three-step review. First, where a utility had estimated program savings based on measured consumption, we reported savings as presented by the utility without passing judgment on the accuracy of the savings estimation.[3] This procedure was used for nine programs.[4] Second, where the utility had

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[2] Keating and Nadel (1992) examined the ratio of pre-program to post-program savings estimates. We examine a related ratio of post-program tracking database estimates to measured consumption estimates. Chapter 5 discusses the differences in these two perspectives.

[3] We are aware that the savings provided to us by several of the utilities are currently being reviewed in regulatory proceedings.

[4] For program evaluations that relied on billing analyses of both participants and a comparison group, a separate

estimated energy savings based on measured consumption for a previous program year, we calculate the ratio of the measured consumption estimate to the tracking database estimate from the previous year and apply the previous year's ratio to the current program year.[5] This procedure was used for two programs (Pacific Gas and Electric (PG&E) and San Diego Gas and Electric (SDG&E)). Third, where energy savings estimates were based only on a tracking database, we adjusted energy savings using the average of the measured consumption/tracking database adjustment factors for the nine of the first 11 programs where such adjustment factors were available. The average adjustment factor was found to be 75% (see Table 5-4). We adjusted the energy savings of the final nine programs in our data set using this 75% measured consumption/tracking database adjustment factor. The development of this adjustment factor and the influence of our use of this procedure on the total resource cost of the programs is explored in Chapter 5.

Free riders are customers who participate in a utility's program but who would have installed measures that are the same as, or similar to, those offered by the utility even without the program.[6] Because free riders essentially take program dollars from utility ratepayers and provide no net savings for the utility, utilities adjust their savings estimates downward to obtain a more precise measure of the savings that are attributable to their programs.[7] For purposes of this analysis, we included the energy savings from free riders in order to develop a measure that indicates total program energy savings and that is consistent with the utility cost data. That is, since costs incurred by all parties are included in our analysis, we must also include the savings accrued by all parties, including free riders.[8]

We approached our adjustments for free-ridership in the same way we approached our

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adjustment is made later for free riders. See discussion following.

[5] See Chapter 5 for the development of this adjustment. Although this ratio is related to what has been termed a *realization rate* in the DSM program evaluation literature, there is some confusion over the exact definition of a realization rate. Consequently, we have chosen to avoid using the term, instead referring to the ratio less succinctly, but more precisely, as the "measured consumption/tracking database adjustment factor".

[6] In Chapter 5, we observe that the phenomenon of free-ridership is generally not defined coherently and not consistently measured by current utility evaluations.

[7] We note that the additional savings resulting from free drivers (customers who install energy-saving measures offered by the utility but who do not participate in the utility's program) are rarely included in utility estimates of the savings from their programs. Unlike free riders, who primarily represent transfers of dollars between ratepayers and participants, free drivers represent net gains to society as a result of a utility's program.

[8] Although this method is consistent with the total resource cost framework, we acknowledge that this framework does not make explicit the effect of free-ridership on electricity rates. We describe this effect of free-ridership in Chapter 4.

adjustments for energy savings. For 17 programs, we used the free-ridership estimates provided by the utility. Because one program (Seattle City Light (SCL)) relied on an evaluation method that corrected for free riders endogenously (i.e., a billing analysis) yet did not estimate free-ridership with a separate evaluation (as did the other utilities relying on billing analyses), we assumed free riders to be 17%, based on the mean free-ridership for the 17 programs mentioned above. Because their free-ridership estimates were determined by a collaborative process, we also substituted our 17% free-ridership estimate for the two programs offered by Green Mountain Power (GMP). The fact that the collaborative process involved extensive negotiations among various parties led us to believe that our 17% estimate was more plausible than those the utility used for the two programs. For example, it was estimated that there were no free riders in GMP's Small C/I Program; this estimate contrasts sharply with the much higher estimates for other small C/I programs that base their free rider estimates on participant surveys and other measured data.

Generally speaking, the savings information on the programs we reviewed did not consider lighting amenity changes. Some of the savings estimation methods did account for the energy impacts of the interaction between lighting and HVAC technologies. Where utilities did address this interaction, they considered only energy relationships between electricity-consuming technologies.

3.1.2 Costs

The total resource cost of energy efficiency acquired through utility-sponsored commercial lighting programs can be split into measure costs and program administrative costs. Measure costs are the costs of acquiring, installing, and operating an energy efficiency measure. These are the costs that a customer adopting the measure could expect to bear in the absence of a utility program. In a utility program, the utility may bear some or all of these costs. For example, rebates transfer some of the capital and installation costs of an energy efficiency measure from the customer to the utility; in direct installation programs, the utility bears all of the measure costs.[9]

Administrative costs are the non-measure costs borne by the utility in implementing programs that lead to installation of efficiency measures (Berry 1989). These costs

[9] Logically, other agents, such as contractors, engineering firms, vendors, etc., will also incur costs as a result of involvement in the program. Conventionally, it is assumed that these agents are fully compensated by the primary agents to the transactions, either the utility or the customer.

represent the cost to ratepayers and society of utility intervention in demand-side markets.[10]

The measure and administrative costs incurred by the utilities were generally well-documented, although we found that assignment of costs to specific categories was reported inconsistently (see Section 4.5.1).[11] For five programs, utility cost information for the commercial lighting component of a multi-technology program was not separated, or only partially separated, from total program costs. For the three of these programs where almost all energy savings were attributable to lighting measures (Boston Edison Company (BECo), GMP Small C/I, and SCL), we used the total costs and energy savings for each program in our calculations. For New England Electric System's (NEES) Energy Initiative Program, in which lighting measures account for 74% of program energy savings, we attributed 74% of program costs to the program's lighting component; this estimate is likely to be high because administrative costs for lighting are generally lower than for other technologies. For GMP's Large C/I Program, in which 58% of savings were attributable to lighting measures, the incentive cost of the program's lighting component was available but the administrative component was not. In this case, we used the ratio of the lighting incentives to total program incentives (45%) to estimate the lighting portion of administrative costs. As with GMP, this is likely to be an overestimate of the costs attributable to lighting savings.

We chose not to include information on the cost to the utility of measurement and evaluation (M&E) of program savings. M&E costs were identified for 11 programs; our utility contacts informed us, however, that the M&E expenditures in the current year were most likely used to evaluate the savings from previous program years. In addition, to calculate M&E costs accurately, some portion of the ongoing costs of program tracking and accounting would also need to be included. We chose instead to develop a set of costs that correspond to the energy savings achieved in the current year of program operation. Chapter 5 reviews the costs associated with program evaluation. This review indicates that the effect of including these costs would increase the utility component of the total resource cost of programs by about three percent (see Figure 3-1 and Section 5.7).

10 We do not consider the extent to which utility programs reduce or eliminate the so-called "hidden costs" of energy efficiency, which may otherwise prevent adoption of measures. Hidden costs refer to costs borne by program participants that arise when various factors preventing adoption of these measures without the utility program are not completely eliminated through participation in the program (e.g., interruption in the workplace during a retrofit). For a discussion of this issue, see Herman and Chamberlin (1993).

11 It is particularly difficult to allocate administrative overhead and measurement and evaluation costs consistently because they are often tracked for a utility's overall DSM activities rather than on a program-specific basis.

Customer cost contributions are the critical difference between a utility and total resource cost perspective on the costs of DSM (Krause and Eto 1988). For utility programs that do not pay the full incremental cost of a DSM measure, omission of the customer cost contribution will understate the total resource costs of DSM. Comparisons of DSM programs that rely only on utility costs will be misleading because of differences in program rebate levels.

For more than half of our 20 programs, the utility estimated the cost of the program to participating customers. Wherever possible, we relied on utility-reported estimates of customer costs. Twelve utilities provided complete information on total customer cost contributions; for five of these twelve programs, there was no cost to the participant. Two more utilities (PG&E, Bangor Hydro-Electric Company (BHEC)) provided information on the cost of the efficiency *measures* to the customers, but did not include the cost of *installation*, for which customers were entirely responsible. For BHEC, our utility contact stated that installation costs account for approximately 20% of the total cost of parts and labor for the program. For PG&E, we relied on a recent LBL report on the cost of energy-efficient lighting to determine installation costs (Atkinson et al. 1992). The report indicated that, for a wide range of lighting efficiency measures, installation costs are approximately equal to equipment costs.

For the remaining six programs, we relied on the design of the rebate (e.g., "pays 50% of installed cost") to estimate the cost of the program to participants. Where the reported rebate level referred to the measure cost rather than the installed cost (e.g., "pays 100% of the equipment cost"), we added in installation costs based on information from the LBL report mentioned above.

Changes in ongoing non-energy costs that result from the adoption of energy efficiency measures, such as the costs of operation and maintenance, are another component of the total resource cost of energy efficiency. These cost changes are generally thought to accrue to the customer, but there may also be ongoing program costs assignable to the utility. None of the studies we reviewed considered these costs explicitly.

Throughout this report, all costs are indexed to 1992 using a time series of GNP implicit price deflators from the *Economic Report of the Office of the President*.

3.1.3 The Economic Lifetimes of Installed Measures

The economic lifetimes of the measures installed through commercial lighting DSM programs are currently the most uncertain inputs to the calculation of the cost-effectiveness of these programs because the expected life of most commercial lighting measures exceeds the time period over which post-program evaluations have been conducted. As a result, we are forced to rely on estimated measure lives. In Chapter 5, we review current studies of short-term measure persistence and demonstrate the effect of alternative lifetime assumptions on our findings for the total resource costs of the programs.

The program evaluations we reviewed most often provided estimates that appeared to be based on equipment lifetimes. These estimates ranged from 14 to 18 years. For two of the shorter estimates (seven and 10 years, for Central Maine Power (CMP) and Central Hudson Gas and Electric (CHG&E), respectively), utility contacts informed us that equipment failure and early removal were considered when the economic lives of the measures were estimated. However, the shortest economic lifetime estimate (five years for Sacramento Municipal Utility District (SMUD)) was based on equipment lifetimes; this program replaced standard fluorescent lamps with more efficient fluorescent lamps.

3.1.4 The Time Value of Savings

In essence, the adoption of energy-efficiency measures represents the substitution of capital today for energy savings tomorrow. From an economic perspective, the wisdom of making this substitution depends on the present value of the savings that are expected to accrue in the future. Specification of a discount rate to reflect alternative uses of this capital is the conventional means for evaluating this trade-off.

Each utility must specify such a discount rate when justifying the value of its programs relative to some other activity the utility might have engaged in.[12] To enhance comparability, we have chosen to use a single real discount rate of 5% for this purpose. This choice is consistent in real terms (i.e., net of inflation) with the range of nominal discount rates encountered in the utility information that we reviewed.

We calculate the total resource cost for each program by using the discount rate to levelize total costs over the average economic lifetime of installed measures for each program. The

[12] The value of this alternative activity is typically measured by an avoided cost.

levelized costs are then divided by annual energy savings. The total resource cost, also known as the cost of conserved energy (Meier 1982), provides a basis for comparing demand-side energy savings with supply-side resource options.

3.2 The Total Resource Cost of Commercial Lighting Programs

We find the mean total resource cost of our 20 commercial lighting programs, weighted by energy savings, to be 3.9¢/kWh. The simple average is 4.4¢/kWh with a standard deviation of 1.9¢/kWh, and the median is 4.4¢/kWh. All costs are expressed in 1992 dollars. Table 3-1 reports the total resource costs for our sample of 20 commercial lighting programs as well as the elements used to calculate them. Figure 3-1 summarizes the total resource costs graphically.

Joskow and Marron (1992), relying primarily on 1991 data from 12 utility-sponsored commercial lighting programs, found the simple average of levelized costs to be 3.6¢/kWh with a standard deviation of 2.8¢/kWh (both figures have been re-expressed in 1992 dollars). Joskow and Marron further observed that the data they examined were incomplete or unverified, typically did not provide estimates of customer cost contributions, and relied on pre-program engineering estimates of savings. Our efforts to address these data limitations confirm Joskow and Marron's conclusion that their levelized cost findings understate the total resource cost of utility energy-efficiency programs.

Our results indicate that, for our sample of commercial lighting programs, the total resource cost of energy efficiency resulting from a comprehensive and accurate accounting of program costs and savings is approximately 20% higher[13] than Joskow and Marron's findings. Although our results are not strictly comparable, they do not support Joskow and Marron's general conclusion that, by not accounting for these factors, the costs of energy efficiency have been understated "by a factor of two or more on average."

We also find that lighting programs have been cost-effective. Table 3-1 reports the TRC test ratio of utility avoided costs (see Chapter 2) to total resource costs. A ratio in excess of 1.0 indicates that the program benefits, based on a utility's avoided cost, outweigh the cost of the program. It is our understanding that all of the programs were initially projected by

[13] This ratio is calculated using the simple average of the costs of conserved energy for the 20 programs rather than the lower weighted average.

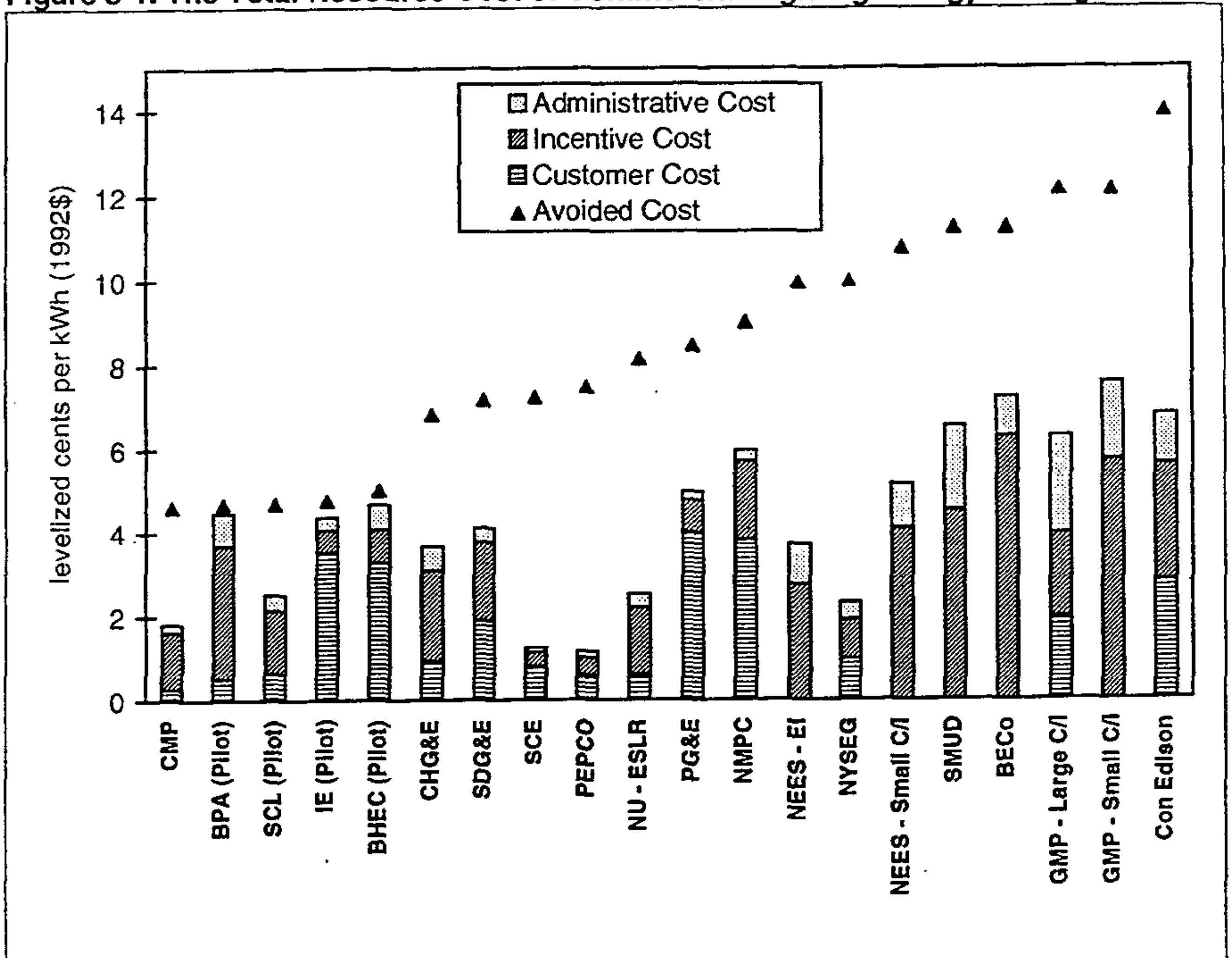
Table 3-1. The Total Resource Cost of Commercial Lighting Energy Savings

Utility	Program Year	Gross Annual Energy Savings (GWh)	Economic Lifetime of Measure (years)	Admin. Costs of Utility ($,000)	Incentives Paid by Utility ($,000)	Customer Costs ($,000)	Levelized Total Resource Cost (¢/kWh)[1]	TRC Test Ratio[2]
BECo	1991	8.3	15.0	$792	$5,433	$0	7.2¢	1.6
BHEC (Pilot)	'86-'88	2.8	10.0	$94	$132	$528	4.7¢	1.1
BPA (Pilot)	'86-'87	3.2	15.0	$199	$805	$133	4.5¢	1.1
CHG&E	'90-'91	16.1	10.0	$708	$2,689	$1,152	3.7¢	1.9
CMP	1992	15.7	7.0	$172	$1,232	$251	1.8¢	2.5
Con Edison	1991	91.9	11.0	$8,943	$21,496	$21,496	6.8¢	2.1
GMP - Large C/I	1992	1.4	14.7	$251	$217	$212	6.3¢	1.9
GMP - Small C/I	1992	4.0	6.1	$284	$888	$0	7.6¢	1.6
IE (Pilot)	1990	1.4	12.0	$29	$51	$329	4.4¢	1.1
NEES - EI	1991	104.2	18.0	$11,701	$33,680	$0	3.7¢	2.7
NEES - Small C/I	1991	23.5	15.0	$2,561	$10,039	$0	5.2¢	2.1
NMPC	1991	134.4	13.0	$2,464	$17,933	$36,418	6.0¢	1.5
NU - ESLR	1991	149.8	17.0	$5,313	$27,301	$10,098	2.5¢	3.2
NYSEG	1991	71.5	10.0	$1,612	$4,007	$4,007	2.3¢	4.3
PEPCO	90-'91	40.5	9.5	$450	$1,282	$1,770	1.2¢	6.4
PG&E	1992	130.0	15.9	$2,406	$9,626	$50,086	5.0¢	1.7
SCE	1992	96.6	12.9	$680	$2,268	$5,515	1.2¢	5.8
SCL (Pilot)	1990	16.9	16.0	$616	$2,683	$1,150	2.5¢	1.9
SDG&E	1992	66.2	15.0	$1,562	$8,478	$8,635	4.1¢	1.7
SMUD	1988	2.6	5.0	$173	$392	$0	6.5¢	1.7
				Itemized Costs per kWh Saved:			**Total:**	
Weighted Average				**0.5¢**	**1.7¢**	**1.7¢**	**3.9¢**	**1.9**
Average				**0.7¢**	**2.3¢**	**1.3¢**	**4.4¢**	**1.3**
Standard Deviation				0.6	1.7	1.4	1.9	2.1

[1] Levelized total resource costs and avoided costs are calculated at a 5% real discount rate.

[2] See Table 2-5 for avoided costs.

Figure 3-1. The Total Resource Cost of Commercial Lighting Energy Savings



Notes:

1) Levelized total resource costs and avoided costs are calculated at a 5% real discount rate.
2) Utility avoided costs are calculated by LBL from utility TRC test ratio estimates and utility estimates of program levelized costs, see Table 2-5.
3) Evaluation costs are not included in utility costs; based on the programs that do report these costs, we estimate that evaluation costs increase the utility component of total resource costs by about 3%. See the discussion of this issue in section 5.7.
4) Free riders' costs and savings are included in the calculation of levelized total resource costs. See the discussion of this issue in section 3.1.1.
5) We rely on utility post-program estimates of savings based on measured consumption data, and make no judgement on the accuracy of utility evaluation methods. For utilities who do not base post-program savings estimates on measured consumption data, we adjust their tracking database estimates of savings by the adjustment factor explained in section 5.2.

the utilities to be cost-effective by this criterion. Based on our detailed re-estimation of program costs (i.e., systematic accounting for customer cost contributions and reliance on post-program savings evaluations), we conclude that all 20 programs remain cost-effective.

Joskow and Marron also express concern that the wide variation among costs of programs represents a major source of uncertainty. If this uncertainty is irreducible, it represents an important additional liability to be considered in selecting energy efficiency resources. However, we believe the detailed information we have developed reduces this uncertainty considerably. The first reduction in uncertainty is achieved by accounting for missing costs and relying on more precise estimates of savings.[14] The second reduction is achieved by relating selected program design features and aspects of program implementation to program costs.

First, a comment on methodology. Although information on 20 commercial lighting programs represents at least twice the amount of information that has been previously examined at this level of detail (see, for example, Krause et al. 1989, and Joskow and Marron 1992), ours is nonetheless a small sample. Multi-variate regression analysis is clearly not viable for samples of this size. Consequently, we focus on trends as indicated by differences in means and associated standard deviations. Where appropriate, we will indicate the statistical significance of these differences using t-tests[15] with varying confidence intervals.

Table 3-2 compares mean total resource costs for three subsets of the 20 programs. We find that there are apparent economies of scale in commercial lighting programs. The seven programs saving less than 15 GWh/year saved energy at a mean cost of 5.9¢/kWh. The 13 programs saving more than 15 GWh/year had a mean cost of 3.5¢/kWh. The difference between these two means is statistically significant at the 99% confidence level.

We hypothesized that economies of scale may be associated with participant savings. As shown in Table 3-2, total resource costs in programs with the smallest savings per participant (less than 30 MWh/participant/year) are slightly — but not significantly —

[14] The relative precision of our unweighted mean is 44% (1.9/4.3); for Joskow and Marron's sample, the relative precision of the unweighted mean is 78% (2.8/3.6).

[15] A t-test measures the statistical significance of the difference between two means. The significance is expressed using confidence levels, which refer to the likelihood that the difference is not random. The higher the confidence level, that smaller the chance that the difference is random.

higher than in programs with the largest savings per participant (more than 80 MWh/participant/year). Programs with moderate savings per participant (between 30 and 60 MWh/participant/year), however, had significantly higher total resource costs than programs with smaller participant savings or than programs with larger participant savings (significant at the 93% and 99% confidence levels, respectively). These counter-intuitive findings may be the result of confounding factors or the small size of our sample.

Table 3-2. Explaining Variations in the Total Resource Cost of Commercial Lighting Programs

Program Savings[1]	Number of Programs	Mean Total Resource Cost (¢/kWh)	Std. Dev.
< 15 GWh/year	7	5.9	1.2
> 15 GWh/year	13	3.5	1.7
Participant Savings[2, 3]			
< 30 MWh/participant/year	12	4.3	2.0
30 < x < 60 MWh/participant/year	4	5.9	0.9
> 80 MWh/participant/year[4]	4	3.1	1.3
Avoided Cost[5]			
< 8¢/kWh	9	3.1	1.4
> 8¢/kWh	11	5.4	1.7

Notes:

[1] The difference in total resource cost is significant at the 99% confidence level.

[2] The difference in total resource cost between programs with smallest savings/participant and moderate savings/participant, and between programs with largest savings/participant and moderate savings/participant are significant at the 99% confidence level.

[3] A definition of participant can be found in Chapter 4.

[4] No programs saved between 60 and 80 MWh/participant/year.

[5] The difference in total resource cost is significant at the 99% confidence level.

Fundamentally, the total resource cost of energy efficiency is a function of the cost of the measures installed and the energy saved by these installations. We observed in Chapter 2 that there was an important difference between the variety of measures offered by a program and the actual distribution of measures installed (and underlying this, the operating characteristics of the installations themselves). Utility avoided costs provide indirect evidence that these differences were implicitly acknowledged in program design and implementation. For example, several programs were implemented at times when the projected avoided costs of electricity were high.

Higher avoided costs, other things being equal, mean that more costly energy savings (either in the form of more expensive measures or increased utility administrative costs) are cost-effective. We find evidence that the design of more expensive programs was associated with high avoided costs. Table 3-2 compares means of program total resource costs for different ranges of avoided costs. The mean cost of programs developed with avoided costs in excess of 8.0¢/kWh is 5.4¢/kWh, while the mean cost of programs developed with avoided costs of less than 8.0¢/kWh is 3.1¢/kWh. This difference is statistically significant at the 99% confidence level.

3.3 The Societal Cost of Free Riders

Table 3-3 presents additional information on the utility administrative costs of conducting these programs. These figures approximate the added cost incurred by society when utilities administer energy-efficiency programs. To the extent that the savings would not have occurred but for the utility's programs, the administrative costs are also an estimate of the size of the market barriers preventing their adoption in the absence of the utility program.

We find that utility administrative costs, weighted by energy savings, represent about 0.5¢/kWh or approximately 13% of the mean total resource costs of the programs. The simple mean is 0.7¢/kWh, with a standard deviation of 0.6¢/kWh.

The total resource costs of DSM programs are not significantly affected by free riders. The impact of free riders is limited to only the additional utility administrative (not incentive) costs of a program (Krause 1989). On the one hand, the utility incentives received by free riders represent transfers between the utility and the free rider but do not affect the total resource cost of the measure (unless some unique aspect of the utility program causes the direct costs of energy-efficiency measures to increase or decrease). On the other hand, additional utility administration costs are required in order to run a program for participants who would have adopted measures in the absence of the program. Therefore, the impact of free riders on the cost of an energy efficiency program depends on the number of free riders and the magnitude of program administrative costs.

Table 3-3 reports free rider percentages (with adjustments, as discussed in Section 3.1) along with the additional utility administrative costs resulting from the participation of free riders in our 20 DSM programs. We conclude that free riders have had a very small impact on the total cost of the energy saved as a result of utility-sponsored commercial lighting programs (ranging from no effect on program cost at all to a maximum of 1.6¢/kWh, with

Table 3-3. Administrative Costs and Free Rider Effects on the Total Resource Costs of Energy Savings

Utility	Administrative Cost / kWh Saved (¢/kWh)[1]	Free Rider Fraction (%)[2]	Additional Administrative Cost of Free Riders (¢/kWh)
BECo	0.9	14	0.15
BHEC (Pilot)	0.6	73	1.60
BPA (Pilot)	0.8	0	0.00
CHG&E	0.6	3	0.02
CMP	0.2	21	0.05
Con Edison	1.2	5	0.06
GMP - Large C/I	2.3	17	0.49
GMP - Small C/I	1.8	17	0.39
IE (Pilot)	0.3	44	0.25
NEES - EI	1.0	7	0.07
NEES - Small C/I	1.1	7	0.08
NMPC	0.3	13	0.04
NU - ESLR	0.3	10	0.03
NYSEG	0.4	22	0.11
PEPCO	0.1	21	0.04
PG&E	0.2	23	0.06
SCE	0.1	15	0.02
SCL (Pilot)	0.3	17	0.07
SDG&E	0.3	18	0.08
SMUD	2.0	0	0.00
Weighted Average	0.5	—	0.06
Average	0.7	17	0.18
Standard Deviation	0.6	16	0.35

1 Administrative costs per kWh saved are calculated from data in Table 3-1.

2 Free rider estimates based on collaborative negotiations are replaced by the average of the other estimates (GMP Large and Small C/I programs). Utility estimation of free riders is discussed in Chapter 5.

the second largest effect being 0.49¢/kWh). In other words, based on the weighted averages, free riders have increased the average utility administrative cost by 0.06¢/kWh, or approximately 12%. Because utility administrative costs from our programs average only 13% of the total resource cost of the energy-efficiency savings, based on the weighted averages, the net societal impact of free riders has been to add less than two percent to these costs.

3.4 Summary

The total resource cost for each of the 20 commercial lighting programs is presented in Figure 3-1. In this report, we consider the total resource cost of a program to be the total cost of the efficiency measures delivered through the program levelized over the lifetime energy savings achieved by the program, using a 5% real discount rate. Our findings directly address shortcomings that have been identified for previous estimates of total resource costs by (1) relying on post-program evaluations of energy savings rather than unverified pre-program estimates, and (2) accounting for the direct costs borne by both the utility and the participating customer, rather than only those costs borne by the utility.

We find that the average cost of the 20 lighting programs is 4.4¢/kWh (in 1992 dollars), ranging from a low of 1.2¢/kWh to a high of 7.6¢/kWh. Weighted by energy savings, the average cost of the programs is 3.9¢/kWh. We find that utility administrative costs, weighted by energy savings, represent about 0.5¢/kWh or approximately 13% percent of the mean total resource costs of the programs. To the extent that the savings would not have occurred but for the utility's programs, these administrative costs are also an estimate of the size of the market barriers preventing their adoption in the absence of the utility program.

The ratio of the utility's avoided cost to the total resource cost for each of the 20 programs we examine is greater than 1.0, indicating that each is cost-effective.[16]

Many of the factors that result from program design choices can be systematically related to observed variations in program costs. For example, we find that the largest programs, as measured by total annual energy savings, have been substantially less expensive on a cost

[16] In standard DSM terminology, this ratio is referred to as the Total Resource Cost (TRC) Test.

per kWh basis than the smallest programs. In addition, Figure 3-1 suggests that many aspects of program design and implementation are influenced by the avoided costs of the utilities; several of the more costly programs were developed by utilities facing very high avoided costs.

Other Measures of the Performance of Commercial Lighting Programs

One of the foremost goals of utility-sponsored lighting efficiency programs is the acquisition of a cost-effective energy resource in the context of an integrated resource plan. In Chapter 3, we assert that the total resource cost of a commercial lighting program is the most important measure of the performance of the program in this regard. In this chapter, we turn our discussion to three additional, often-cited measures of program performance:

- participation rates,
- energy savings per participant[1], and
- utility costs per participant.

We critically examine these measures in order to understand precisely what aspects of program performance they measure. We pay particular attention to the methodological issues associated with consistent specification of participation rates and distinguish the value of participation rates for internal utility management from their value for other purposes such as cross-utility comparison.

4.1 Measures of Program Performance

Previous comparisons of DSM programs have emphasized numerous measures of program performance. Flanigan (1992), for example, presented more than 20 indices by which to measure the success of DSM programs. The indicators included large energy and/or demand savings; successful targeting of specific customer groups; energy and/or demand savings exceeding projections; high participation rates; rapid program delivery; systematic design and retrofits as opposed to cream skimming; large energy and/or demand savings per customer; large program budget; large dollar expenditures per customer; low-cost savings; and low administrative costs. Nadel (1991) used a more abbreviated approach and focused on program costs, energy and demand savings, cost-effectiveness, and participation rates as measures of program performance.

[1] Although demand savings are also a common measure of program success, the primary goal of the programs we examine in this report is energy savings.

For this discussion, we have chosen to focus on three broad, interrelated measures of program performance. It is commonly thought that successful DSM programs (1) have *high participation rates*, (2) *maximize energy savings per participant*, and (3) *minimize* utility costs per participant. Yet, none of these features — a high participation rate, large energy savings per participant, or low utility costs per participant — guarantees a cost-effective DSM program. Trade-offs among program objectives are likely. For example, a high participation rate may come at the expense of higher utility costs per participant because of increased marketing costs and/or the need to pay larger incentives to attract additional participants. Maximizing savings per participant might lead to higher utility costs per participant because of the need for more site-specific auditing as well as incentive approaches that are tailored to the needs of certain customers. In addition, given a fixed program budget, the maximization of savings per participant may result in a lower participation rate. Minimizing costs per participant may require the utility to offer smaller rebates and thus have difficulty in attracting a large number of participants.

In short, it is unclear that any one of these three objectives is appropriate if pursued independently of the others. For this reason, we believe that the total resource cost remains the appropriate "bottom-line" against which inevitable trade-offs among these other measures of program performance should be considered. The appropriateness of a specific performance measure will then depend on the perspective one uses in examining DSM programs (e.g., acquiring a cost-effective resource, meeting internal organization objectives, or comparing program performances among utilities).

4.2 Program Participation

Attracting large numbers of customers to a DSM program is considered by some to be one of the most critical factors affecting a program's performance (Nadel, Pye, and Jordan 1994): the higher the participation rate, the more successful the program. From a resource planning perspective, the implicit assumption is that more participants will lead to greater energy savings for the program, so long as savings per participant do not decline and utility marketing costs do not increase disproportionately. Underlying this perspective is the belief that there is a specific number of customers who would be willing to participate in a specific energy-efficiency program and that the program should reach all potential customers as fast as possible. From the related but somewhat different perspective of the people who plan and implement DSM programs, a high participation rate indicates a successful marketing campaign. Underlying their perspective is a utility's internal program-planning process in which DSM budgets and specific programmatic marketing goals are defined annually.

Although achieving high participation rates is important from both the resource planning and program implementation perspectives, the actual measurement of participation rates is not a straightforward process. As described below, we find that neither the numerator (the number of program participants) nor the denominator (the number of customers eligible to participate in the program) used to calculate participation rates is defined consistently and precisely among utilities. In addition, even when utilities define participation consistently, other issues (such as repeat participation and the criteria used to limit the size of the eligible population) complicate comparison of participation rates among utilities. Comparing participation rates also requires consideration of the length of time a program has been operating (program maturity) and of the resources devoted to program implementation (program budget).

4.2.1 Defining Program Participants and Eligible Participants

An important barrier to consistent measurement of participation rates for DSM programs, particularly in the non-residential sectors, has been the absence of standard terms and protocols for defining program participants and eligible program participants. Certainly, it is easier to define and collect data on participation rates for some sectors and for some end uses than it is for others. For example, in residential weatherization programs, where most utility-sponsored DSM activities originated in the late 1970s, the simplest and most logical unit by which to define a participant is the owner/occupier of a single-family dwelling. The owner/occupier both inhabits the dwelling and pays the utility bill; he or she is therefore the decision maker who can choose to participate in a DSM program. Defining the eligible population in the case of residential weatherization is also straightforward. Because there is generally one account number per household, the number of eligible participants can be assumed to be the number of residential account numbers. Thus, the number of participants divided by the number of residential account numbers gives a reliable participation rate.

This basic model for calculating a participation rate in a residential weatherization program breaks down when applied to commercial customers participating in lighting efficiency programs. In the commercial sector, the decision to participate in a DSM program might be made by the owner of a building but could also be made by a building tenant. For owners of franchises, such as chains of restaurants or department stores, the decision to participate in a DSM program may be made by someone in the regional or national headquarters.

In our sample of 20 commercial lighting programs, program participants were generally defined as "account numbers", "customers", or "rebates paid". As the following discussion reveals, the use of these various terms for defining program participation makes it difficult to compare participation rates among utilities.

"Account Numbers"

The use of "account numbers" as the defining units for program participation in small commercial enterprises can resemble the residential weatherization scenario described above, where there is one tenant or owner/occupier per building and the number of "customers" directly corresponds to the number of account numbers. Many small businesses, like most residences, have only one account number. Iowa Electric Light and Power Company (IE), for example, processed only one rebate application per customer, and each customer had only one account number. The program was available to all commercial and industrial customers within a given service area, so the eligible population was equal to the number of C/I account numbers in that service area.

The one-to-one correspondence between a single "customer" and an account number is less common for larger enterprises, however. On the one hand, large companies and industries can have multiple account numbers. A chain of grocery stores in a single town, for example, is likely to have an account number for each store. On the other hand, one account number can represent a large number of buildings. One utility contact told us that a city block full of buildings at a local university has a single account number, and would thus be considered a single participant in one of their DSM programs.

"Customers"

The use of "customers" as the defining units for program participation can also have a variety of meanings. Often, "customer" is synonymous with "business" or "company" and indicates an organization with a single owner. A customer can be a small business occupying part or all of a building or can be a much larger organization. For Sacramento Municipal Utility District (SMUD), counting customers corresponded closely to counting account numbers because the businesses participating in their program were small and generally had only one account number. In contrast, Consolidated Edison of New York (Con Edison) counts "unique customers". In this case, a bank with several branches would be considered a single participant even if each branch had its own account number. For the Bangor Hydro-Electric Company (BHEC) program, a single "customer" is considered to be a single decision maker. According to our BHEC contact, a multi-site paper mill where one person has the authority to decide that the whole organization will participate in a DSM program would be counted as one participant - even though the mill has 10 account numbers or applies for two rebates per site. On the other hand, if the individual site managers had the authority to decide to participate in a DSM program, each site would be considered a program participant.

"Rebates Paid"

The use of "rebates paid" as the defining units of program participation, like the use of "customers", can have a variety of meanings. "Account numbers" and "customers" sometimes correspond to single rebates and sometimes do not. Our Southern California Edison (SCE) contact asserts that the number of rebates the utility paid through the lighting component of the 1992 Energy Management Hardware Rebate Program is roughly equal (within 10%) to the number of account numbers, because there is usually no more than one application per account number.

In addition, rebates sometimes correspond to a single efficiency measure (a lighting control system, for example) and other times correspond to a large number of measures. According to one utility contact, when a local club was given more than 10,000 compact fluorescent bulbs to resell for $3/bulb, the transaction was considered to be a single rebate. In contrast, large businesses housed in multiple buildings might submit one rebate application for each structure. Multiple rebate applications per customer are particularly common in multi-technology programs where the application for efficient lighting equipment is likely to be separate from the application for other types of measures (such as efficient HVAC equipment).

If the number of rebates paid corresponds directly to a number of account numbers or a quantifiable number of customers, rebates can be used to determine a participation rate. When numerous rebates are available to single customers or account numbers, however, it is difficult to determine the number of potential rebates and thus difficult to determine a participation rate. Nadel's research (1990) indicates, for a limited sample of programs, an average of 1.75 rebates paid per account number; we did not have the necessary data, however, to determine whether or not that ratio is applicable to our sample of lighting programs.

Complications of Comparison Among Terms Defining Program Participants

Participation rates determined by the three general terms described above have important internal uses for utilities. As long as participation is measured consistently, a utility can compare participation rates among its own DSM programs and over a number of years for a single program. Because the terms used to define participation vary among utilities, comparisons of participation rates among different utilities are less straightforward. One must ensure that the units used to compare participation among utilities are defined in the same way. According to our Central Maine Power (CMP) contact, for example, a participating customer could be the owner of a single business that has three account numbers and receives two rebates per account number. CMP, because they track "rebates paid", would consider this to be six participants; a utility tracking "account numbers" would consider this to be three program participants; and a utility tracking "customers" is likely to consider this to be only one participant.

Criteria for Limiting the Size of the Eligible Population

Comparing participation rates among utilities can also be complicated by the different ways that utilities define the number of customers eligible for program participation. In our sample of 20 lighting programs, the number of eligible participants was most commonly defined as either the total population of C/I customers in a given service area or the portion of the C/I customer population that met specific criteria (see Section 2.2.3). In the latter group, eligibility was specific to the program. For Boston Edison Company's (BECo) Small C/I Retrofit Program, for example, only non-residential customers with a peak demand of less than 150 kW were eligible (see Table 2-2(a)).

Generally, for programs that define a subset of the entire C/I population as eligible, participation rates will tend to be higher. For example, Bonneville Power Administration's (BPA) program was available only to high-ceilinged C/I warehouse facilities in one county; because of these limiting eligibility criteria, the program was available to only 207 participants. Consequently, with only 24 participants, BPA had a participation rate of 11.6% over two years. In contrast, Central Hudson Gas and Electric (CHG&E) offered incentives to all of its C/I customers. Although the CHG&E program had close to 50 times as many participants in a single year as BPA had during the two-year life of its program, CHG&E's annual participation rate was only 3% because the program was available to the approximately 35,000 account numbers — CHG&E's entire C/I customer classes.

Repeat Participation

Even when the terms used to define participation are consistent, determining a participation rate can be complicated by those who participate more than once in a single DSM program. Repeat participation is especially common for large commercial customers. Returning to our residential example, in most weatherization programs a participant receives incentives for efficiency measures (such as ceiling insulation or weather stripping) that, once installed, will not need to be installed again in the near future. Businesses with larger facilities, however, may use an ongoing DSM program to retrofit separate buildings or even wings or floors of the same building over the course of several years. If the business submits a new rebate application each year and is counted as a separate participant each year by the utility sponsoring the program, the resulting cumulative participation rates can be inflated. As discussed below, repeat participation is particularly important in lighting programs because new technologies are often offered by the programs each year and satisfied former participants often wish to reapply.

In addition to considering the defining terms, repeat participation, and the limiting criteria of the eligible population, in order to compare participation rates among utilities one must consider the length of time a program has been operating (program maturity) and the resources devoted to program implementation (program budget).

4.2.2 Program Maturity

Because program planners and marketing staff members are often evaluated on how well a DSM program performs in a given year, they are often interested in annual participation rates. Resource planners within utilities, however, are more likely to be interested in cumulative participation rates because these rates are indicative of the lifetime energy savings potential of a DSM program. Because most analysis of DSM programs is done on a yearly basis, it is important for researchers and evaluators to understand how participation rates can change over the life of a program. In the early years of a DSM program, as word slowly spreads about the program, participation rates are typically low. As the market delivery system matures, however, participation rates should become higher and more indicative of the overall performance of the program. For example, BHEC's pilot lighting program paid only 16 rebates in its first year (1986) but provided rebates to more than 130 participants by the end of 1988 (resulting in a 1.4% cumulative participation rate). Similarly, NEES's Small C/I Program had 666 participants in its first year, followed by 2,152 participants in the second year, and 2,494 in the third (resulting in a 9.7%

cumulative participation rate). Finally, Niagara Mohawk Power Corporation (NMPC) had 2,393 participants in its first year, followed by 2,881 in the second year, and 4,755 in the third. Thus, for programs that have only been operating for one to two years — as have the majority of programs we examine in this report — annual participation rates may not be as meaningful as cumulative participation rates.[2]

As mentioned above, repeated participation in a DSM program by a single customer can artificially inflate cumulative participation rates. Because the weatherization measures installed through residential programs have generally not changed enough to warrant cost-effective repeat participation, repeat participation is unlikely in these programs, and cumulative participation rates are thus useful indicators of market saturation.[3] This is not the case for commercial DSM programs that offer efficient lighting technologies. During the last few years, energy-efficient lighting technologies have changed dramatically in availability, cost, and features offered. Although commercial programs may be stable in their overall design, the availability of newer, more cost-effective technologies suggests that the eligible population is in fact growing over time. Therefore, as noted earlier, satisfied participants in an older version of an existing program may be excellent candidates for renewed participation because of their prior familiarity with the utility's program and their previously demonstrated desire to take advantage of better technologies. Consequently, the eligible population for commercial lighting programs will be a moving target as long as technological innovations continue to bring newer, cost-effective technologies into the market; saturating the market for a fixed set of commercial lighting technologies is therefore not a reasonable goal.

4.2.3 Program Budget

One of the most important impediments to cross-utility comparisons of participation rates is the internal constraint on participation established by the annual DSM budgeting process of most utilities. Some programs ramp up quickly, deplete their allocated budgets, and are then suspended until additional funds are available and/or financial incentives are reduced in order to curb demand. Most utilities wish to avoid this stop-and-go process and plan for a gradual phase-in of their programs; typically, a small pilot program is initiated and, after

[2] After a program has had several years to mature, however, the annual participation rate may become a more reliable indicator of how well a program is reaching its customers.

[3] In certain situations, revisiting weatherization customers may be feasible if the initial program had low measure saturation and if the marginal cost justifies the investment.