The Total Cost and Measured Performance of Utility-Sponsored Energy Efficiency Programs

*Joseph Eto, Edward Vine, Leslie Shown, Richard Sonnenblick, and Chris Payne**

By examining the actual performance of conservation or demand-side management (DSM) programs for ten utilities, Joskow and Marron (1992) have made an important contribution to policy discussions about the wisdom of relying on utilities to improve customer energy efficiency. We use Joskow and Marron's method to analyze twenty utility commercial lighting programs and, like Joskow and Marron, find wide variations in industry reporting practices and savings evaluation methods. We extend the method by systematically accounting for several of the most important sources of variation and comment on how they influence total program costs. Our accounting also allows us to relate remaining program cost variations to the program sizes and the electric supply costs avoided by the programs. We draw qualified, yet affirmative, conclusions regarding the cost effectiveness of the programs.

INTRODUCTION

Since the late 1980s, the U.S. utility industry has invested over 9 billion ratepayer dollars in demand-side management (DSM) programs (Energy Information Administration 1994). The recent growth in utility DSM spending can be traced to the belief by utilities and their regulators that DSM, in particular energy or conservation savings, are a cost-effective resource for meeting customer energy service needs (Krause and Eto 1988). Utility reliance on DSM has been challenged by, among others, Joskow and Marron (1992),

The Energy Journal, Vol. 17, No. 1.

* All the authors are with the Energy Analysis Program, Energy and Environment Division, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, MS 90-4000, Berkeley, CA 94720, USA. E-mail: jheto@lbl.gov

who observe that utilities currently document the costs and evaluate the savings from DSM programs in very different ways and that these differences tend to bias the cost of energy savings downward from their correct (higher) values. Joskow and Marron conclude that "[b]etter utility cost accounting procedures and the application of more sophisticated methods to estimate actual energy savings achieved are clearly necessary before large sums of money can be expended wisely on these programs." The implied conclusion is that, when corrected for biases, many DSM programs will not be cost effective.

Using Joskow and Marron's method, we arrive at different conclusions. We adopt the definitions and life-cycle cost accounting framework developed by Joskow and Marron and apply it to 20 utility commercial lighting programs. Although we encountered many of the same difficulties Joskow and Marron faced in accounting for the full costs and measured energy savings of DSM programs, we demonstrate that many of these difficulties can be successfully addressed or otherwise accounted for. Once we separate the impact of these differences between utility reporting and savings measurement approaches from real differences in the design and operation of utility DSM programs, we find that the 20 programs have been cost effective.

We then discuss the wisdom of utility reliance on DSM as a resource. We agree heartily that the measured performance of DSM programs is the most appropriate basis for making these decisions. However, we accept that all resource planning decisions must contend with uncertainty; decisions to run DSM programs are no exception. In this regard, we do not conclude that the risks to ratepayers currently posed by uncertainties in program costs make decisions to rely on DSM unwarranted.

ANALYTIC FRAMEWORK

Joskow and Marron's analytic framework focuses on determining the life-cycle cost of energy efficiency investments. The real life-cycle cost per kWh saved for utility DSM programs consists of four elements:

I: The incremental total resource cost of the program, as defined below.
E: The annual kWh savings from the program.
r: The real discount rate (we use 5%, following Joskow and Marron).
L: The economic lifetime of the savings.

The real life-cycle cost per kWh saved, LCC, is the incremental total resource cost, levelized by the discount rate over the economic lifetime of the savings, divided by annual kWh savings.

$$LCC = \frac{CRF(r,L)*I}{E} \quad (1)$$

where the capital recovery factor, CRF, is

$$CRF = \frac{(1+r)^{L-1}}{r*(1+r)^{L}} \quad (2)$$

The incremental total resource cost of the programs consists of several classes of costs and two sources of offsetting benefits:

Kd: The total installed cost of a DSM measure, part of which may be borne by the utility, part of which may be borne by the customer.

Ka: Additional costs incurred by the utility to implement the program that delivers a measure, including measurement and evaluation.

Ko: Administrative overhead allocated to the program.

O: Net present value of other changes in costs associated with the adoption of the DSM measure (which may be either positive or negative).[1]

Ad: The total installed cost (if any) of the energy-using device or measure that would have been installed in the absence of the customer's participation in the utility's DSM program.

The sum of the first three terms, less the final two terms, is the incremental total resource cost of the program.[2]

1. This term in Joskow and Marron's accounting framework can include important costs and benefits not traditionally considered by utilities, but well-recognized by economists, such as the welfare effects of utility price increases due to DSM programs. We do not address these effects in this paper.

2. Like Joskow and Marron, we found little information on the economic salvage value of equipment retired prematurely through DSM programs (which would modify *Kd* or *Ad*, depending on one's perspective) or on the net effect of other cost changes associated with adoption of the DSM measures (*O*).

$$I=Kd+Ka+Ko-O-Ad \quad (3)$$

We extend Joskow and Marron's analytic framework by comparing the life-cycle cost of the energy efficiency investment to the societal benefit from the investment, as measured by avoided electricity supply costs. Dividing this benefit (which, by convention, is also expressed as a cost per kWh) by the cost yields a quantity known as the total resource cost (or TRC) benefit-cost test ratio (California Public Utilities Commission and California Energy Commission 1987). A ratio greater than one indicates an investment is cost effective; that is, the expected benefits exceed the expected costs.

TWENTY UTILITY COMMERCIAL LIGHTING PROGRAMS

Joskow and Marron examined entire portfolios of utility conservation or energy efficiency DSM programs; we examine only commercial lighting programs. Technical potential studies routinely show that lighting has enormous potential for cost-effective efficiency improvements (Energy Information Administration 1992). As a result, commercial lighting programs are often the largest single program within a utility's DSM portfolio. While most utility DSM programs are expected to be cost effective, many are motivated by other, legitimate regulatory objectives, such as customer service or equity (Blumstein and Harris 1993).[3] Commercial lighting programs, by contrast, are pursued primarily because they are thought to be a highly cost-effective resource option.

Taken together, the 20 lighting programs we examined represent nearly $170 million of utility spending on DSM. Although spread over different years, this spending is equal to about 15% of 1992 total U.S. utility spending on DSM; it is an even higher percentage of utility spending on energy efficiency DSM (utility DSM spending also includes load management and load building programs). The Appendix lists the utilities that provided us with information on their DSM programs.

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 programs we studied varied in sizes, maturities, delivery mechanisms, technologies offered, and targeted customer populations.[4]

3. We do not address the question of whether DSM is the most efficient way to address these other regulatory objectives. Our point is simply that DSM predicated on these other objectives should not be held only to a standard for cost effectiveness appropriate for DSM programs whose primary objective is acquisition of a cost-effective resource.

4. More detailed information on the programs can be found in Eto, et al. 1994.

Sixteen programs were full-scale programs and, on average, accounted for 25% of each utility's budget for energy efficiency programs (see Table 1). Only five of these sixteen had been in full-scale operation for more than two and a half years. The four remaining programs were new, small-scale, pilot programs.

Table 1. Fraction of Utility DSM Budgets Represented by Commercial Lighting Programs and Total Utility DSM Costs (1992$)

Program Code	Year	Cost of Program to the Utility ($millions)	Total Utility Expenditures on Electric Energy Efficiency Programs ($millions)[a]	Program Costs as % of Total Electric Energy Efficiency Expenditures (%)
1	1991	6.2	38.4	16
2	86-88	0.2	n.a.	n.a.
3	86-87	1.0	221.1	>0
4	90-91	3.6	4.9[b]	73
5	1992	1.4	16.4	9
6	1991	32.2	76.5	42
7	1992	0.5	4.6	11
8	1990	1.2	4.6	26
9	1991	0.1	n.a.	n.a.
10	1991	45.9	87.6	52
11	1991	13.4	87.6	15
12	1991	20.7	42.8	48
13	1991	33.6	100.0	34
14	1991	5.8	23.5	25
15	1990	1.8	20.9	9
16	1992	12.4	118.0	11
17	1992	3.0	63.1	5
18	1990	3.4	n.a.	n.a.
19	1992	10.3	28.9	36
20	1988	0.6	8.8	7

n.a. denotes data unavailable.

[a]In some cases, the figure may include elements of a DSM budget that are not related to energy efficiency, such as load retention.

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

Sixteen programs offered financial incentives to customers in the form of rebates for purchase of energy-efficient lighting equipment such as compact fluorescent lamps, electronic ballasts, high-efficiency magnetic ballasts, reflector systems, T-8 efficient fluorescent lamps, T-12 efficient fluorescent lamps, lighting controls (e.g., occupancy sensors), and high-intensity discharge lamps. Rebate amounts, types, and delivery mechanisms differed significantly from program to program (see Table 2). For our analysis, all rebates were converted into and expressed as fractions of the total, direct, out-of-pocket costs incurred by customers who purchased and installed efficient equipment. Four programs (referred to as "direct install") offered free lighting equipment and installation to customers. Many programs were developed with specific customer populations in mind (e.g., large versus small commercial customers) although determining the actual size of participating customers is complicated by differences in the way participants are defined.[5]

Table 2. Overview of Twenty Commercial Lighting Programs

Program Code	Life-Cycle Stage	Program Type	Incentive Level (% of installed cost)
1	Full-Scale	Rebate	100
2	Pilot	Rebate	20
3	Pilot	Rebate	86
4	Full-Scale	Rebate	70
5	Full-Scale	Rebate	83
6	Full-Scale	Rebate	100
7	Full-Scale	Audit, Rebate	55
8	Full-Scale	Direct Install	100
9	Pilot	Rebate	11
10	Full-Scale	Audit, 100% Rebate	100
11	Full-Scale	Direct Install	100
12	Full-Scale	Rebate	33
13	Full-Scale	Info, Audit, Rebate	73
14	Full-Scale	Rebate	50
15	Full-Scale	Rebate	42
16	Full-Scale	Rebate	19
17	Full-Scale	Rebate	35
18	Pilot	Audit, Rebate	70
19	Full-Scale	Audit, Rebate	54
20	Full-Scale	Direct Install	100

In principle, these variations should be evident in program cost differences. However, we first had to account for the different ways in which utilities currently report costs and measure savings.

5. We found three commonly used definitions of participant: customer account number, customer site or facility (potentially having more than one account), and rebate paid (possibly retrofitting only a portion of a customer's site/account).

DEVELOPING COMPREHENSIVE AND CONSISTENT INFORMATION ON COSTS AND SAVINGS

Developing consistent information on utility DSM programs is difficult. Joskow and Marron identify a number of critical problem areas: (a) missing utility costs; (b) missing customer costs; (c) differences in savings evaluation methods (some programs use tracking databases, while others use pre- and post-program consumption data); (d) differences in assumptions regarding measure lives; and (e) ignoring or incorrectly accounting for free riders. To this list we add a sixth: (f) not accounting for the effects of free drivers and program spillover. Finally, in order to examine the cost effectiveness of DSM programs, we also develop information on (g) avoided electricity supply costs. Our data collection and analysis efforts permit us to address (a), (b), (c), (e), and (f) directly, but not (d) and (g), since they rely on assumptions regarding the future. For these two items, we instead discuss the risks associated with these uncertainties.

In order to estimate the total resource cost of the energy saved by the programs, we considered only those programs for which we could obtain post-program cost and energy savings data. This requirement limited our analysis to only 20 of the more than 50 programs we originally considered. Of the programs we selected, fewer than half included in their formal evaluation reports all of the information essential for our analysis in a usable form. Data were often missing or inconsistent, reported in varying levels of detail, sometimes with different definitions used for the same terms. We expended considerable time and effort developing a consistent, comparable data set for our analysis, seeking information from other published materials (e.g., utility filings with regulatory commissions) and contacting utility program managers and evaluators by telephone. Extensive discussions with utility staff members (over a period of weeks and sometimes months) were required to obtain additional information, to clarify the information initially provided by the utilities, and to verify that we were treating the data appropriately. Close contact with utility staff members also allowed us to take advantage of their insights and to obtain program data that were more accurate or more recent than the data available in published sources.[6]

It is incorrect to conclude that utilities intentionally report misleading or inconsistent information on program costs. Utility reporting is typically

6. The bias potentially introduced by our strict information requirements could either understate or overstate costs. On the one hand, utilities with better programs may be more willing to submit them to examination. On the other hand, the programs we examined have generally been the subject of greater regulatory scrutiny and reporting requirements. In any case, we did not encounter resistance to our information requests that we could confidently trace to concerns regarding program performance.

dictated by regulatory orders and these orders vary from utility to utility. Indeed, prior to Joskow and Marron's work, the value of systematic comparison of DSM programs, which would benefit from standardization in reporting, was not widely appreciated. While we were rarely able to find all the information needed for a comprehensive measure of program costs in a single document, we were usually able to find most of the information we needed through our utility contacts, provided it had been collected and could be made available in a form we could use.

However, with Joskow and Marron, we second Hirst's call for industry adoption of standardized cost accounting and energy savings reporting systems analogous to the existing FERC system for reporting financial data and operating information (Hirst 1989). Adoption of standard terminology and reporting formats will facilitate future comparative evaluations of DSM program performance.

Including All Utility Costs

We found that the total measure and administrative costs incurred by the 20 utilities we studied were generally well documented. However, several utilities did not report subprogram components of their administrative costs. When utilities did report administrative costs by component, components varied widely from utility to utility. As Berry (1991) has noted, the lack of standardized definitions for administrative cost components makes it difficult to compare these costs among programs. It was particularly difficult to allocate administrative overhead, and measurement and evaluation (or M&E) costs consistently because they are often tracked for a utility's overall DSM activities rather than for each program.

We developed a conservative procedure to allocate administrative costs for the five lighting programs that did not identify these costs separately. In some cases, we allocated all costs to lighting when lighting appeared to account for the majority of program savings. In other cases, we allocated costs proportionally to each subprogram according to the energy saved by the subprogram in relation to the total program.

We could not consistently identify M&E costs for inclusion in calculating total costs of DSM programs because post-program M&E activities are generally conducted (and costs are accounted for) after the year in which the original DSM program is offered and are generally not reported for individual DSM programs. Thus, it was difficult to associate costs consistently with particular programs and program year. For the 12 programs where they could be identified, M&E costs in the program year (but not necessarily spent to evaluate savings from that program year) averaged less than 3% of total utility costs (before including customer costs). For consistency in making program comparisons, we used this average to impute an M&E cost for the remaining programs, but note that simply omitting M&E costs would have had little effect on the total costs of the programs.

Accounting for Customer Costs

We systematically included customer contributions in our calculation of total program costs. Whenever possible, we relied on utility-reported estimates of customer costs. Twelve of the 20 utilities provided complete information on customer cost contributions. Two other utilities provided information on the customers' cost for efficiency *measures*, but not *installation*, for which customers were entirely responsible. We adjusted the customer costs at these two utilities using recent work examining energy-efficient lighting system costs.[7] Our adjustments doubled the installed costs of the measures. Six utilities provided information on the design of their rebate, which we used to infer customer cost contributions.

Reconciling Differences Between Energy Savings Evaluation Methods

We based all the energy savings in our analysis on post-program evaluations rather than pre-program plans. Estimates were either taken directly from evaluation reports and verified by utility contacts or were received directly from utility contacts. The energy savings for nine of the 20 programs were based on utility tracking database information, which often included significant post-program information, such as the specific equipment that each participant installed and customer-reported or site-verified hours of operation. Energy savings estimates for the remaining 11 programs were based on analyses of customer billing information and/or end-use metering.[8]

Within the DSM community, there is considerable debate over the merits and shortcomings of different evaluation techniques, especially over the value of energy savings estimates based on a tracking database versus energy savings estimates based on measured consumption data (such as end-use metering or billing data). We found that, where both post-program tracking database estimates and post-program measured consumption estimates of savings were available, discrepancies between the two were often significant. For the nine programs where both were available, the ratio of measured consumption

7. Atkinson, et al. 1992 conducted detailed cost analyses for 15 lamp product and four fixture product classes (each product class contained between 3 and 11 energy efficient technologies) in order to evaluate minimum efficiency standards for lighting products. Equipment costs were developed through an explicit weighting of price quotes from a variety of sources. Installation costs were developed using industry labor and cost estimates.

8. See Eto, et al. 1994 for a detailed description of the savings evaluation methods used by the utilities.

estimates to tracking database estimates ranged from 0.53 to 1.26 (see Table 3). Weighted by energy savings, the measured consumption estimates equal approximately 75% of the tracking database estimates. These findings are consistent with the widely-cited findings of Nadel and Keating (1991).

Table 3. Post-Program Measured Consumption Results Compared to Post-Program Tracking Database Results

Program Code	Evaluation Methods Used[a]	Measured Consumption/ Tracing Data Base Ratio[b]
4	SAE	1.05
5	EU SI	0.81
6	SAE	0.93
10	EU SAE	0.53
11	EU BA	0.78
13	EU SI SAE	0.69
15	BA	1.26
16	EU BA	0.89
18	BC	0.71
19	BA	0.66
Weighted Average[c]		0.75

[a]BA = Billing data analysis using regression model; BC = Simple billing data comparison; EU = End use metering; SAE = Statistically adjusted engineering estimate; SI = Site inspection.
[b]The measured consumption/tracking database ratio is the ratio of the savings estimates obtained using each evaluation method to tracking database savings estimates.
[c]The average is weighted by energy savings.

In order to compare the energy savings from the 20 programs consistently, we adjusted savings estimates for nine of the 11 programs that were based on tracking database results by applying a measured consumption/tracking database adjustment factor of 75%. For two programs, a ratio of the measured consumption estimate to the tracking database estimate was available for a previous program year, so we applied the previous year's ratio to the current year's tracking database estimate.[9] We did not adjust savings estimates for the nine programs whose savings were estimated using measured consumption data.

9. The ratios from these previous years were 0.89 and 0.66.

Recognizing Differences in the Economic Lifetime of Savings

Estimates of savings lifetimes represent a major source of uncertainty for the cost of DSM programs because there have been few studies covering the entire life cycle of DSM program measures. Overestimates of measure lifetimes affect the cost of saved energy disproportionately. Assuming, for example, a cost of 4.0 ¢/kWh calculated using a lifetime of 13 years, a one-year reduction in the lifetime increases the cost by 6%; a three-year reduction increases cost by 22%; and a five-year reduction increases cost by 45%.

The estimates of savings lifetimes reported by the utilities generally appear to be based on equipment lifetimes, but we found several estimates that reflected conscious efforts by the utilities to account for actual operating conditions (such as expected hours of operation) and persistence (both degradation of savings from a measure, and premature retirement). Utilities' procedures for making these estimates were not uniform. In the end, we chose to rely on the utilities' estimates of measure lifetimes, weighted where possible by the actual distribution of measures installed. The program lifetimes ranged from 5 to 18 years with a mean of 12.4 years and standard deviation of 3.7 years.

Accounting for the Effects of Free Riders

Free riders are program participants who, even without a DSM program, would still have installed the efficient equipment promoted by the program. We agree with much of Joskow and Marron's discussion of the topic, in particular that: (1) utility incentive payments to free riders are transfer payments and do not, in and of themselves, represent net societal costs; (2) it is difficult to specify appropriate comparison groups to use in measuring free ridership;[10] and (3) there are an often overlooked, dynamic aspects to free ridership.[11]

Our treatment of free riders differs slightly from that Joskow and Marron's. They eliminate both the costs and savings from free riders from a calculation of the cost of energy saved by a utility program, because these

10. See Train (1994) for a recent discussion of this methodological issue.

11. The dynamic aspect of free ridership is, in fact, directly related to the economic lifetime of savings. That is, for those program participants that at some time would have adopted a measure offered by the utility's DSM program (and thereby become a free rider), that point in time represents the end of the economic lifetime of the savings from the measure. The DSM program, in this case, has accelerated the adoption of a measure. This aspect of free ridership is not widely acknowledged and, as it is intimately related to the economic lives of savings is difficult to address empirically with precision. It can be accounted for as an adjustment either to the traditional static measure of free ridership or to the economic lifetime of savings.

savings cannot be attributed to the program (they would have occurred even without the program). We choose, instead, to include both costs and savings from free riders because it is practically impossible to separate free rider costs from the aggregate totals reported by the utilities. Moreover, when administrative costs are relatively small (as we found them to be), including both results in only slight differences to final cost of saved energy.

Free ridership percentages were reported for 19 of our 20 programs. We inferred a free ridership percentage for the twentieth program and for two of the remaining 19 programs that had developed their free ridership percentages through a collaborative negotiation between regulator and utility. The inferred free ridership percentage was based on the simple average of the free ridership rates reported by the other 17 programs (17%, with a standard deviation of 18%[12]).

Observations on Free Drivers and Program Spillover

Although utilities have devoted substantial effort to estimating free ridership for most of the 20 programs, few utilities have attempted to measure free drivers and program spillover. Free drivers are nonparticipants who install efficient equipment as a result of hearing about a program or program measures from customers with firsthand program experience or through other means.[13] Program spillover occurs when program participants install additional efficiency measures, without rebates, as a result of their participation in the program.[14] Both effects are the flip-side of the dynamic aspect of free ridership that Joskow and Marron describe: in these instances, the utility program has accelerated the adoption of conservation technologies offered by the program to program nonparticipants and of additional conservation technologies to program participants.

Both free drivers and program spillover effects reduce the total cost of energy efficiency because they increase the energy savings attributable to the programs with no increase in utility administrative costs. In effect, the utility's program administrative costs can be spread over a larger base of savings. Several utilities had begun to consider this issue for the programs we examined (Table 4), but neither they nor we have included these savings in our estimates. In this regard, our findings are conservative; including the costs and savings from free drivers and program spillover would reduce the cost of the programs.

12. The free ridership estimates ranged from 0% to 73%.

13. The Pacific Gas and Electric Company recently completed a study that provides preliminary documentation for this phenomena in the commercial sector (Cambridge Systematics Inc. 1993).

14. Levine and Sonnenblick (1994) recently found evidence of program spillover for Massachusetts Electric Company's commercial sector rebate programs.

Table 4. Evidence of Free Drivers and Program Spillover from Evaluation Surveys

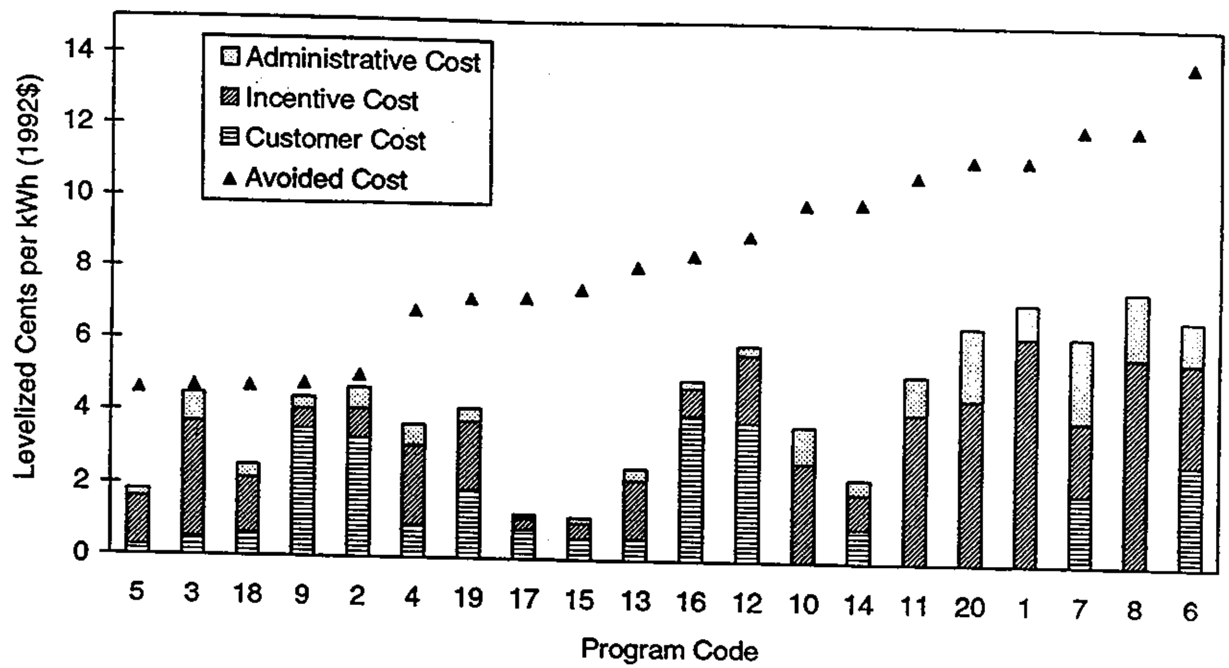
Program Code	Affirmative Responses		Survey Question
	Participants	Nonparticipants	
4	25%	not asked	Influenced by program to buy efficient equipment on your own?
10	65%	not asked	Would you now install equipment w/o a rebate?
11	51%	not asked	Would you now install equipment w/o a rebate?
13	51%	13%	Influenced by program to buy efficient equipment on your own?

Measuring the Value of DSM with Utility Avoided Costs

From a least-cost planning perspective, the net societal value of DSM is measured by the difference between the full costs of DSM programs, as detailed above, and the electric supply costs these programs allow the utility to avoid. We reviewed utility filings and related information developed in the program planning stages to determine the electricity supply costs the utilities estimated would be avoided by the commercial lighting programs. These costs were re-expressed using a 5% real discount rate. We refer to these costs to comment on the cost effectiveness of the programs and help explain variations in program costs.

However, avoided costs, like the costs of energy efficiency, are not free from bias or error. Future avoided costs are projections that rely on many forecasted quantities, such as the future price of natural gas. The administrative determination of avoided costs, moreover, relies on a host of complicated technical considerations, often arbitrated in semi-public, quasi-legalistic regulatory forums, which are likely to be influenced by political considerations (Kahn 1995). For example, several programs we examined were developed in states that included environmental externality adders in their avoided costs. We chose not to include these adders because they were not used for all programs, and because their measurement is controversial (Joskow 1991).

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



Total resource costs (utility administrative, utility-paid incentive, and incremental customer-borne costs) and avoided costs are levelized using 5% real discount rate. Free riders' costs and savings are included in the calculation of total resource cost. Energy savings based on tracking database have been adjusted to ensure greater consistency with energy savings based on analyses of measured consumption data. Avoided costs were developed on a program-specific basis from information filed by utilities on the projected cost effectiveness of the programs.

Table 5. The Total Resource Cost of Commercial Lighting Energy Savings (1992$)

Program Code	Gross Annual Energy Savings (GWh)	Economic Lifetime of Measure (years)	Admin. Costs of Utility ($millions)	Incentives Paid by Utility ($millions)	Customer Costs ($millions)	Levelized Total Resource Cost (¢/kWh)[a]	TRC Test Ratio
1	8.3	15	0.8	5.4	0.0	7.2	1.6
2	2.1	10	0.1	0.1	0.5	4.7	1.1
3	2.4	15	0.2	0.8	0.1	4.6	1.0
4	16.1	10	0.9	2.7	1.2	3.8	1.9
5	15.7	7	0.2	1.2	0.3	1.8	2.5
6	91.9	11	10.7	21.5	21.5	7.0	2.1
7	1.1	15	0.3	0.2	0.2	6.4	1.9
8	3.0	6	0.3	0.9	0.0	7.7	1.6
9	1.1	12	0.3	0.5	0.3	4.4	1.1
10	104.2	18	12.2	33.7	0.0	3.8	2.7
11	23.5	15	3.3	10.0	0.0	5.5	2.1
12	101.4	13	2.8	18.0	36.4	6.0	1.5
13	149.8	17	6.3	27.0	10.1	2.6	3.2
14	53.9	10	1.8	4.0	4.0	2.4	4.3
15	40.5	10	0.5	1.2	1.8	1.2	6.4
16	115.7	16	2.8	9.6	50.1	5.0	1.7
17	72.8	13	0.8	2.3	5.5	1.3	5.8
18	16.3	16	0.7	2.7	1.2	2.6	1.9
19	43.7	15	1.9	8.5	8.6	4.2	1.7
20	2.0	5	0.2	0.4	0.0	6.7	1.7
			Itemized Costs per kWh Saved			Total	
		Weighted Average	0.5¢	1.7¢	1.7¢	4.0¢	2.8
		Average	0.8¢	2.2¢	1.3¢	4.4¢	2.4
		Standard Deviation	0.7¢	1.7¢	1.4¢	2.0¢	1.4

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

THE COST AND COST-EFFECTIVENESS OF UTILITY COMMERCIAL LIGHTING PROGRAMS

As shown in Table 5, the total cost of the 20 programs we examined ranged from a low of 1.2 ¢/kWh to a high of 7.6 ¢/kWh (see also Figure 1). The simple average is 4.4 ¢/kWh with a standard deviation of 2.0 ¢/kWh. Weighted by energy savings, the total cost of the programs averaged 4.0 ¢/kWh.

These findings are quite consistent with those of Joskow and Marron, who report a slightly greater range of costs for commercial sector lighting programs, from 0.5 ¢/kWh to 10.0 ¢/kWh, with a simple average of 3.4 ¢/kWh (and standard deviation of 2.8 ¢/kWh). However, our results reflect systematic adjustments to account for all utility and all measurable customer costs, as well as adjustments to ensure better comparability among the different energy savings estimation methods used. Our results for these specific programs do not support the broad conclusion drawn by Joskow and Marron that "computations based on utility expectations could be underestimating the actual societal cost by a factor of two or more on average." If anything, our results suggest that doubling the sample size and accounting for these differences has reduced the range in program costs with a modest (but not statistically significant) increase in average cost.

We also found customer cost contributions averaged nearly 30% of the total cost of the programs. Clearly, as Joskow and Marron indicate, ignoring these costs understates the true cost of energy savings.

We found program administrative costs averaged 26% of total utility costs (excluding customer cost contribution), which is consistent with earlier findings by Berry (1991). When customer costs are included, program administrative costs fall to about 13% of the total cost of the programs.

The Cost Effectiveness of the Programs

Based on avoided costs developed by utilities, we found all 20 programs to be cost effective from a total resource cost perspective. That is, the total cost of the energy saved by each program was less than the avoided cost that each utility used to justify the program (see Table 5 and Figure 1). At the same time, avoided costs for many utilities have fallen since the programs were initiated. We discuss the implication of changing avoided costs in the penultimate section.

The Societal Cost of Free Riders

The impact of free riders on the cost of energy efficiency differs substantially depending on whether one adopts a societal or utility perspective. From a societal or total resource cost perspective, the net societal impact of free riders has been negligible. Free riders increased the savings-weighted average of program administrative costs by 12%, but because utility administrative costs from the programs average only 13% of the total cost of the programs, the net effect has been to add less than 2% to the total costs of the programs. However, free riders can have a significant effect on the impacts of DSM program costs on utility rates and thus ratepayers. Based on the savings-weighted average for the 20 programs examined, we found that free riders increased utility costs by 17%.[15]

Some Reasons for Variation in Program Costs

Joskow and Marron, reflecting on variations in the costs of saved energy for the DSM programs they examined, conclude that: (1) estimated costs are likely to be sensitive to measurement methods—we have accounted for many important differences in measurement and reporting methods and reduced the variance that differences in measurement methods in program costs appear to have caused; (2) variation in customer attributes and program costs is greater than typically assumed in policy analyses—we have attempted to show that simplifications, made of necessity, need not entail significant biases; and (3) utilities may not be successful in targeting only the most cost-effective opportunities—we agree that there is room for improvement in utility DSM programs. However, we did not find that all remaining variations in costs were random or that they resulted solely from imperfect knowledge on the part of utilities and their regulators, as Joskow and Marron suggest. Instead, we found that cost variations were systematically related to the scale of programs and, more importantly, to a utility's avoided electricity supply costs; see Table 6.[16]

We found that total program costs and savings vary with program size. The largest programs, as measured by total annual energy savings, were substantially (about 40%) less expensive on a cost-per-kWh basis than the smallest programs. Since program budgets are fixed exogenously, usually by agreement between the utility and the regulatory agency, the challenge to the utility is to maximize performance subject to a fixed budget. Our findings indicate that programs with larger budgets have been comparatively more successful in delivering energy savings at lower costs. Thus, we believe our results suggest that there may be economies of scale in the delivery of energy-efficiency programs.

15. DSM programs often have secondary impacts, such as the impact of program costs and free riders on rates. These effects are not addressed in this paper, but can in principle be accounted for in the framework presented by Joskow and Marron. See footnote 1, above.

16. Given the small size of our sample, multiple regression analysis techniques were deemed inappropriate.

Table 6. Explaining Variations in the Total Resource Cost of Commercial Lighting Programs

	Number of Programs	Mean Total Resource Cost (¢/kWh)	Standard Deviation
Program Savings			
<15 GWh/year	7	6.0	1.3
>15 GWh/year	13	3.6	1.8
Avoided Cost			
<8¢/kWh	9	3.2	1.4
>8¢/kWh	11	5.5	1.8

In addition, we found total program costs were higher for programs sponsored by utilities with higher avoided costs. For example, the average total cost of programs developed based on avoided costs in excess of 8.0¢/kWh was roughly 40% higher than the total cost of programs with avoided costs lower than 8.0¢/kWh. This suggests that utilities facing higher avoided costs could afford to design more expensive efficiency programs. For most of the utilities in our sample, high avoided costs were reflective of extremely tight supply/demand conditions in the early 1990s. We know anecdotally that many of these utilities were faced with rolling brown-outs and launched very aggressive (and expensive) DSM programs in response.

DSM AS A UTILITY RESOURCE OPTION

Joskow and Marron demonstrate that a number of uncertainties affect current estimates of the total resource cost of energy efficiency. They imply that accounting for them would lead to negative conclusions regarding the cost effectiveness of DSM programs. We have looked at some of the largest DSM programs in the country and, after accounting for the most important sources of bias, found that they have been cost effective. Despite this, our findings are conditioned on potentially significant, remaining unaccounted for sources of bias, such as changes in the assumed economic lifetime of savings or in avoided electricity supply costs. It is likely that with new information some of the 20 DSM programs may ultimately be judged not cost effective, although we expect most will remain cost effective. The question is whether continued reliance on DSM is warranted in view of this track record. We believe that it is.

We disagree with Joskow and Marron that historically diverse utility accounting and measurement practices, which have led to imprecise estimates of cost, suggest that "[b]etter utility cost accounting procedures and the application of more sophisticated methods to estimate actual energy savings achieved are *clearly necessary* [emphasis added] before large sums of money can be expended wisely on these programs." Historic practices suggest that improvement is welcome and that planners should always endeavor to account for known uncertainties in the planning process.

Whether DSM should remain a part of a utility's resource portfolio ought to depend on whether the perceived costs and the risks, including the utility's ability to meet environmental targets, associated with reliance on this resource are preferable to those associated with the resource alternatives. Clearly, the economic lifetime of savings represents a major unresolved source of uncertainty for the full cost of DSM programs and remains, in our opinion, one of the most important topics for future evaluation efforts. However, uncertain information regarding the lifetime of savings does not undermine the credibility of planning efforts based on estimates of the cost of energy efficiency. Because all information is uncertain, the issue becomes how uncertain is the information, relative to other uncertainties, and who bears the risks associated with these uncertainties.

Judgments regarding the wisdom of utility DSM programs must be made with explicit reference to the alternatives. Better information on the full costs of DSM will help us make these judgments. In this regard, it is instructive to recall that least-cost, now integrated resource, planning arose as a regulatory response to the recognition that traditional resource planning by utilities had produced unacceptable outcomes. These outcomes included unprecedented large disallowances of nuclear plant construction costs. Utility-run DSM programs and non-utility generation emerged as preferred resource options because they held the promise of lowering the cost of meeting ratepayer's electricity service needs, compared to the available alternatives. We would argue that compared, for example, to the devastating economic consequences associated with historic utility reliance on nuclear power, the risks associated with utility reliance on DSM have been clearly preferable.

As the electricity industry enters the second half of the 1990s, the erosion of the monopoly franchise appears inevitable. In a world of regulated distribution companies and comparatively less-regulated power marketers, brokers, and energy service suppliers, DSM programs are sure to change. We would argue, however, that they are unlikely to disappear (Hirst and Eto 1995). Indeed, in order to survive in a more competitive marketplace for retail electricity services, DSM is likely to become an integral element of utility's strategy for maintaining or expanding its market share. We would expect that the demand for better information on the true costs of DSM will increase whenever ratepayer dollars are proposed to support these activities.

CONCLUSION

Our comprehensive look at 20 recent, resource-oriented utility DSM programs confirms the cost effectiveness of these energy efficiency programs, and their viability as a utility resource option. At the same time, DSM is not "too cheap to meter." Utilities must carefully measure the energy savings from programs and account for all costs associated with the acquisition of DSM resources. We strongly recommend accelerated adoption of common terminology and reporting forms to facilitate identification and appropriate adaptation of the best practices.

ACKNOWLEDGMENT

The work described in this paper was funded by the Assistant Secretary for Conservation and Renewable Energy, Office of Utility Technologies, Office of Energy Management of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098. The authors are also grateful for the helpful comments provided by three anonymous reviewers.

APPENDIX

The following utilities contributed information on their DSM programs for use in our study.

Bangor Hydro-Electric
Bonneville Power Administration
Boston Edison
Central Hudson Gas and Electric
Central Maine Power
Consolidated Edison of New York
Green Mountain Power
Iowa Electric Light and Power
New England Electric System
New York State Electric and Gas
Niagara Mohawk Power
Northeast Utilities
Pacific Gas and Electric
Potomac Electric Power
Sacramento Municipal Utility District
San Diego Gas and Electric
Seattle City Light
Southern California Edison

REFERENCES

Atkinson, Barbara A., et al. (1992). *Analysis of Federal Policy Options for Improving U.S. Lighting Energy Efficiency: Commercial and Residential Buildings*. Berkeley California: Lawrence Berkeley National Laboratory, December.

Berry, Linda (1991). "The Administrative Cost of Energy Conservation Programs," *Energy Systems and Policy* 15: 1-21.

Blumstein, Carl and Jeffrey Harris (1993). letter to Christine Gilbert, Letters Editor, *Science* 261: 970.

California Public Utilities Commission and California Energy Commission (1987). *Standard Practice Manual, Economic Analysis of Demand-Side Management Programs.* Sacramento, California: California Energy Commission and California Public Utilities Commission, December.

Cambridge Systematics, Inc. (1993). *Net-to-Gross Ratios for PG&E's CIA Rebate Program, Study B - Manufacturer, Vendor and Contractor Surveys.* San Francisco, California: Pacific Gas and Electric Company, September.

Eto, Joseph, E. Vine, L. Shown, R. Sonnenblick, and C. Payne (1994). *The Cost and Performance of Utility Commercial Lighting Programs*, Berkeley, California: Lawrence Berkeley National Laboratory, May.

Hirst, Eric and Joseph Eto (1995). *Justification for Electric-Utility Energy-Efficiency Programs.* Oak Ridge, Tennessee: Oak Ridge National Laboratory, August.

Hirst, Eric (1989). *Comparison of Energy Information Agency Data Collections: Electricity Supply and Demand.* Oak Ridge, Tennessee: Oak Ridge National Laboratory, October.

Joskow, Paul L. (1992) "Weighing Environmental Externalities: Let's Do it Right!" *The Electricity Journal* 5 (4): 53-67.

Joskow, Paul L. and Donald B. Marron (1992). "What Does a Negawatt Really Cost? Evidence from Utility Conservation Programs." *The Energy Journal* 13 (4): 41-74.

Kahn, Edward (1995). "Regulation by Simulation: The Role of Production Cost Models in Electricity Planning and Pricing." *Operations Research* 43 (3): 388-398.

Krause, Florentin and Joseph Eto (1988). *Least-Cost Planning Handbook for Public Utility Commissioners: Volume 2 - The Demand Side: Conceptual and Methodological Issues.* Washington, DC: National Association of Regulatory Utility Commissioners, December.

Levine, Mark D. and Richard Sonnenblick (1995). "On the Assessment of Utility Demand-Side Management Programs." *Energy Policy* 22 (10): 848-856.

Nadel, Steven M. and Kenneth M. Keating (1991). "Engineering Estimates versus Impact Evaluation Results: How Do They Compare and Why?" in *Energy Program Evaluation: Uses, Methods, and Results, Proceedings of the 1991 Energy Program Evaluation Conference.*

Train, Kenneth E. (1994). "Estimation of Net Savings from Energy-Conservation Programs." *Energy - The International Journal* 19 (4): 423-441.

U.S. Energy Information Administration (1994). *Annual Energy Outlook*, Washington, DC: Energy Information Administration, December.

U.S. Energy Information Administration (1992). *Energy Consumption Series: Lighting in Commercial Buildings*, Washington, DC: Energy Information Administration, March.