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INTRODUCTION

In many regions of the United States and Canada, electric utilities are now the leading sponsors of energy-efficiency programs. Under the title *demand-side management* (DSM), more than 500 utilities have sponsored programs, including approximately 1000 residential programs (1), 400 commercial programs (2), and 400 industrial programs (3). Included among these efforts are *conservation programs* (reducing electricity use), *load management programs* (shifting demand from one time period to another, typically in an effort to reduce peak demand), and *load-building programs* (increasing demand in order to help meet a utility's strategic objectives). Total expenditures on electric utility DSM programs were approximately $2 billion in 1991, and this figure is expected to increase significantly during the 1990s (4). DSM program offerings are particularly numerous in the northeastern, north central, and far western regions of the United States. In Canada, utilities in British Columbia and Ontario are particularly active.

This paper is divided into four main sections. The first section discusses why many utilities have decided to implement DSM programs. It seems counter-intuitive to many observers that a private utility would want to sell less of its product; this section attempts to explain why. The second section reviews a variety of studies that estimate the amount of electricity that can be saved by cost-effective DSM programs. This section reviews studies on both the *technical DSM potential* (the maximum amount of electricity that could be saved if all customers adopt all cost-effective DSM measures, ignoring the many barriers that inhibit adoption of these measures) and the *achievable DSM potential* (the amount of electricity that could be saved from an aggressive set of programs and policies designed to overcome the barriers inhibiting adoption of DSM measures). The third section reviews utility DSM efforts to date, including typical programs and exemplary programs. This discussion covers specific programs as well as overall utility-wide efforts involving many programs. The fourth section is a critical appraisal of current DSM efforts, and includes a discussion of many of the problems that must be overcome if estimates of the achievable DSM potential are to be realized. This section also discusses a number of efforts now under way that seek to address these problems.

In this paper several types of data are reported that merit explanation. *Participation rate* is the cumulative number of customers participating in a program divided by the number of customers eligible for the program. Participation rates reported here generally include free riders (customers who participate in a program but would have implemented a conservation measure even if no program were offered). *Electricity savings* are reported as a percent of the average participating customer's pre-program electricity use. Wherever possible, savings figures reported in this paper are based on a statistical comparison of electricity bills for program participants and nonparticipants. These savings estimates are referred to as *net savings* because savings are net of savings achieved by a control group of nonparticipants. For most programs, net savings figures are unavailable. In these cases, either *gross savings* (savings determined with a billing analysis that does not include a control group) or *engineering estimates* of savings are used, and are so indicated in the text. Cost per kWh saved are based on utility costs (including indirect costs such as staff and marketing), and do not include costs borne by the customer. Unless otherwise stated, costs per kWh are levelized over the assumed life of the measure using a 6% real discount rate.

WHY DO UTILITIES PURSUE DEMAND-SIDE MANAGEMENT?

There are many reasons utilities pursue DSM programs. Not all reasons apply to all utilities, and the importance of the reasons that do apply varies depending on the utility. Still, several rationales apply to many utilities, including:

1. DSM programs are cost-effective.
2. DSM programs increase customer satisfaction.
3. DSM programs can reduce the environmental impacts of power plant siting and use.
4. State regulatory processes require or encourage utilities to implement DSM programs.

These rationales are discussed in the sections below.

Cost-Effectiveness

Utilities have spent many decades searching for inexpensive sources of power and optimizing power plant designs. Efforts to optimize energy-efficiency in customer facilities have rarely received the same level of attention. As a result, many efficiency opportunities are available on the customer side of the meter that cost substantially less per kWh saved than the cost to generate a kWh from a new power plant. In some cases, efficiency measures cost less than the cost to operate existing power plants. For example, the New York State Energy Plan (5) estimates that power from new power plants ranges in cost from $0.05 per kWh to more than $0.10 per kWh, depending on the type of plant, but that DSM programs generally range in cost from $0.014 to $0.050 per kWh. The study further estimates that operating costs for existing power plants are often $0.03 per kWh or more, and thus many DSM programs are less expensive per kWh than existing generating facilities.

Furthermore, owing to large construction-cost disallowances during the

1980s (more than $13 billion of power plant capital investments were denied cost recovery by state and federal regulators), many utilities are fearful that construction costs for new plants may also be disallowed (6). Cost disallowances raise the cost of new power plants to stockholders, thereby making the economics of DSM programs even more enticing to utility managements.

Customer Satisfaction

Demand-side management programs are popular with customers because they reduce customer energy bills, and, in some cases, promote the installation of new equipment that offers added benefits besides energy savings. For example, as a result of a DSM program, customers may receive efficient new lighting fixtures that cause less glare than the fixtures they replaced; or a weatherization job may decrease drafts in a home, making occupants more comfortable. Furthermore, in an era when cleaning up the environment enjoys broad public support, DSM programs often play prominently in utility efforts to improve their environmental image.

Utilities care about customer satisfaction for several reasons. First, in the case of large customers, utilities fear that customers will leave the utility grid and either generate their own power, or (if the electric utility industry is deregulated) purchase electricity from an alternative supplier, thereby decreasing sales and hurting profits. Many utilities believe that dissatisfied customers are more likely to bypass the utility than satisfied customers. As a result, some utilities offer DSM programs as a "plum" to customers who might otherwise bypass the utility grid (7). Second, customers are also voters, and utility commissions often respond to voter concerns. An illustration of this phenomenon is provided by General Public Utilities, which substantially expanded DSM programs in the wake of the accident at their Three Mile Island Power plant.

Environmental Impacts

New power plants can be difficult to site and permit. Furthermore, air and water pollution and hazardous waste disposal problems are often associated with power plants. DSM programs reduce these problems by reducing the amount of power that is needed. In fact, under the Clean Air Act Amendments of 1991, utilities are encouraged to implement DSM programs as part of their compliance strategies (8). Several studies have found that DSM programs can be less expensive per ton of sulfur dioxide removed than scrubbers (9). In addition, several states instruct utilities to include estimates of the value of avoided emissions and other environmental externalities when conducting cost-benefit analyses on DSM programs (10). New England Electric's most recent strategic plan illustrates the importance of these factors; the cornerstone of the plan is to reduce the environmental impact of electric service, and DSM programs feature prominently among the implementation strategies listed (11).

Regulatory Encouragement

Owing in large part to the three factors described above, many state regulatory commissions are very supportive of DSM programs. As a result, commissions have employed a variety of inducements to encourage utilities to implement DSM programs, including direct orders to implement DSM programs, financial penalties for not implementing DSM programs (12), "least-cost planning" requirements under which utilities must implement DSM programs if they are less costly than supply-side alternatives (13), requirements that environmental externalities be included in analyses underpinning resource acquisition decisions, and financial incentives for implementing DSM programs (i.e. providing shareholders with a share of the financial benefits attributable to DSM programs—this issue is discussed further in the next-to-last section of this paper).

In addition to regulatory encouragement, intervenors in the regulatory process may also seek expansion of DSM programs. Sometimes utilities find it preferable to work with intervenors on detailed DSM implementation plans as an alternative to contentious hearing-room battles over DSM issues (14).

DEMAND-SIDE MANAGEMENT POTENTIAL

Several studies have estimated the size of the DSM resource. For example, a 1989 study on the technical potential for conservation and load management (C&LM) savings in New York State estimated that if all C&LM measures that are cost-effective to consumers (assuming a 6% real discount rate) are implemented, statewide electricity use will be reduced by 34% (15). Similarly, a 1990 report prepared for the Electric Power Research Institute (EPRI) found that use of energy-saving technologies could reduce US electricity consumption in the year 2000 by 24–44% (16). Similar estimates have been developed by a number of utilities. For example, studies prepared for Pacific Gas and Electric, Southern California Edison, and the Sacramento Municipal Utility District all estimate a technical DSM potential of 30–35% (17–19). A higher estimate of the DSM technical potential, prepared by the Rocky Mountain Institute, estimates a cost-effective DSM technical potential of more than 70% (20). This estimate is higher than other estimates because of differences in the number of technologies considered, differences in assumptions about technology performance, applicability, and cost, and differences in analytical factors.

However, while technical potential studies are useful for determining the size of the available DSM resource, such studies ignore the many barriers to successful adoption of DSM measures by end-users, as well as the costs necessary to overcome these barriers. In order to address this limitation, several utilities and researchers have investigated the amount of energy savings that can be achieved by cost-effective DSM programs and policies.

For example, in 1990, the American Council for an Energy-Efficient Economy (ACEEE) and the New York State Energy Office (NYSEO) conducted a study to estimate how much DSM savings could be achieved cost-effectively by the state's major electric utilities. For this study, utility DSM programs around the United States, Canada, and Europe were examined, and based on the results of the most successful of these programs (where success meant high participation and high savings, while remaining cost-effective to the sponsoring utility), 21 conservation programs were developed for application by the largest electric utilities in New York State. The study concentrated on efficiency measures that were commercially available in 1990 (load management programs were not included). A further conservatism was that the study assumed that building codes and equipment efficiency standards will be strengthened during the 1990s, hence programs included in the analysis begin where the strengthened standards end (21).

Results of the New York study are summarized in Figure 1. For all three utilities, energy and demand savings in 2000 range from 9 to 17% of projected electricity sales and peak demand. The large range is primarily due to

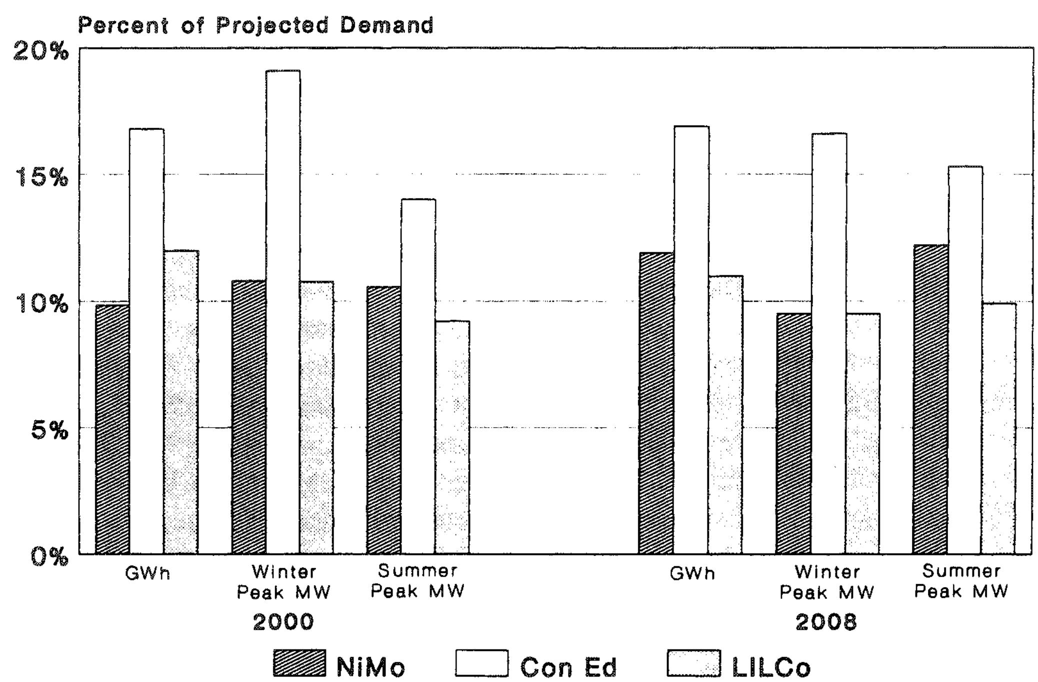

Figure 1 Conservation savings due to utility DSM programs as a percent of projected demand for three New York utilities.

differences in the customer base of each utility—the utility with the largest commercial load, where savings opportunities are greatest, had the highest savings, while the utility with the largest industrial load, where savings opportunities are lowest, had the lowest savings.

In addition to examining achievable savings from utility DSM programs, the ACEEE/NYSEO study examined savings achievable from other mechanisms, including market forces (what would likely happen in the market, even if utilities do not expand their efficiency programs), strengthened building codes, and new and improved equipment efficiency standards. These analyses, which are summarized in Table 1, found that achievable savings due to other mechanisms average 13.6% of projected New York GWh sales in 2008. These savings are approximately equal to achievable savings in New York State from utility programs. Overall, achievable savings from utility DSM programs, market forces, codes, and standards amount to 27% of projected electricity sales in 2008, which represents nearly 80% of the technical savings potential for New York State discussed above (21).

Numerous utilities plan to achieve savings from their DSM programs approaching or equivalent to the New York estimates for utility DSM programs. Figure 2 summarizes planned MW and GWh savings for 22 of these

Table 1 Estimated conservation savings in New York State resulting from market forces, codes, and equipment efficiency standards, year 2008

	GWh savings	% of projected sales
Market forces and existing standards (included in forecast)	8,900	4.6%
Revised codes and standards (for equipment that is currently regulated)		
Refrigerators and freezers	2,700	1.4%
Other residential appliances	2,600	1.3
Lamp ballasts	1,000	0.5
Commercial building code change	5,600	2.9
Total—revised codes & standards	11,900	6.2%
New efficiency standards (for regulations now under consideration)		
Lamps	4,400	2.3%
Luminaires (lighting fixtures)	900	0.5
Motors	1,000	0.5
Commercial packaged HVAC equipment	100	0.1
Subtotal	6,500	3.4%
Overlap between new standards and utility programs	−1,100	−0.6
Total—new standards	5,400	2.8%
Grand total	26,300	13.6%

Source: (21)

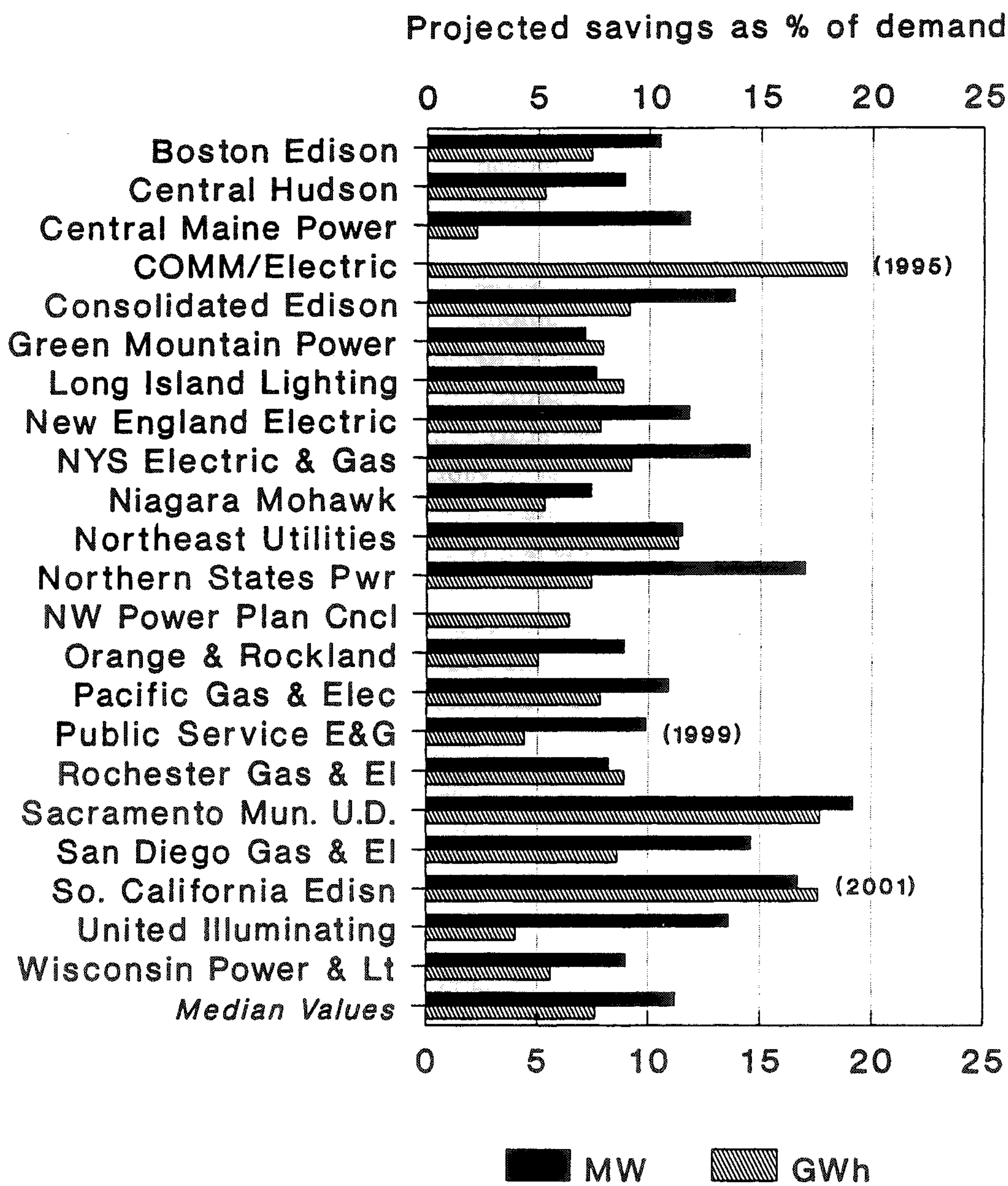

Figure 2 Planned MW and GWh savings for 22 utilities. Annual savings for the period 1991–2000 are reported as a percent of predicted 2000 peak demand and GWh sales before DSM savings are subtracted. Dates in parentheses indicate end-years other than 2000.

utilities (22). Savings for the period 1991–2000 are shown as a percent of predicted 2000 peak demand and GWh sales before DSM savings are subtracted. Projected incremental DSM savings range from 2 to 19% of electricity sales in 2000 and 8 to 19% of peak demand in 2000 (median values of 7.6% and 11.2%, respectively).

DEMAND-SIDE MANAGEMENT EXPERIENCES

Program Types and Results

In this paper seven types of DSM programs are discussed: information, load management, rebate, loan, performance contracting, comprehensive direct installation, and bidding.

INFORMATION PROGRAMS Information programs range from simple educational brochures that are mailed to customers to industrial energy audits. Hundreds of information programs have been run by utilities, but program results are rarely compiled or published. The limited data that are available indicate that information programs can have a positive impact, but that participation rates and savings are usually limited. For example, Collins et al (23) found net or gross energy savings of 0–2% among recipients of pamphlets, videos, and other energy-saving information services.

Perhaps the most common type of information program is the energy audit. Most US utilities (electric and gas) offered residential energy audits during the 1980s as part of the federally mandated Residential Conservation Service (RCS) program. According to an evaluation of the program (24), six years after the RCS program began, approximately 7% of eligible customers had participated in the program. Evaluations of the program found audited households had average net savings of 3–5% (25). Some programs had higher participation rates and savings. Factors linked with high participation and savings included a high degree of state and utility commitment to the program, the provision of financial assistance, and assistance arranging measure installation (24).

Similar participation rates and savings are typical with commercial audit programs, although a few programs that emphasize personal, one-on-one marketing, and that provide financial incentives, have achieved participation rates up to 90% and net savings up to 8%. Commercial rebate programs typically cost the utility $0.01 per kWh saved (26).

LOAD MANAGEMENT PROGRAMS Common load management programs include air-conditioner and water-heater cycling (primarily residential sector), interruptible rates [commercial and industrial (C&I) sectors], and time-of-use rates (all sectors).

In a cycling program, in exchange for an incentive, customers permit the utility to use a timer or radio-controlled switch to shut off customer equipment during peak periods. Nationwide, the average incentive payment per customer is approximately $25–30 per year (1). Davis et al (27) report on a number of air-conditioner and water-heater cycling programs that have achieved participation rates of 25% or more, including a few programs with participation rates of approximately 50%. Factors linked with high participation include high incentives, program duration (participation rates tend to increase steadily with time), and an intensive marketing effort including print and broadcast media and direct mail. Savings per customer average approximately 0.9 kW for air-conditioner programs (typically each air conditioner is cycled off for 20 minutes each hour) and 0.6–1.0 kW for water heater programs, with savings towards the upper end of this range in the winter (1). However, savings per customer vary with climate and cycling schedule. Savings increase as the length of the shutoff period increases, but the longer the shutoff period the more likely customers are to complain of discomfort or lack of hot water.

In an interruptible rate program, customers agree to reduce their demand during peak periods when requested by the utility. In exchange, customers receive a discount on their electric bills. The size of the discount depends on the demand reduction; one study found an average incentive of $85 per kW annually (3). These programs are primarily oriented towards large C&I customers. Participation rates are generally low (even the most successful programs typically only include a few hundred customers), but load reductions per customer can be significant (up to several MW) and overall load savings substantial. For example, one study of 50 industrial programs found average contracted reductions of 1.5 MW per customer and 105 MW per program [actual reductions are generally less than contracted reductions (3)].

Time-of-use rates vary the cost of energy by season or time of day. Rates are higher during periods of peak demand and lower during off-peak periods. Some utilities have made time-of-use rates mandatory for large C&I customers. In the residential sector, time-of-use rates are often limited to electrically heated homes—other homes do not use enough electricity to justify the cost of time-of-use electric meters, which is several hundred dollars more than the cost of standard meters. One review found that peak load savings from C&I programs averaged 1% and peak savings from residential programs ranged from 6 to 20%. However, savings from time-of-use rates vary depending on the size of the peak/off-peak price differential and the length of peak period—it is easier to shift loads out of a two-hour period than out of a 12-hour period (28).

REBATE PROGRAMS Rebates are probably the most common type of financial incentive offered by electric utilities (26). In the residential sector, rebates are commonly offered for the purchase of efficient appliances and compact fluorescent lamps. In the C&I sectors, lighting rebate programs and multiple end-use rebate programs (i.e. programs that provide rebates for measures affecting several different end-uses) are most common, followed by air-conditioning and motor rebate programs. Most rebate programs pay rebates equal to 20–50% of the cost of a DSM measure.

In the C&I sectors, the vast majority of rebate programs have achieved cumulative participation rates of less than 4% of eligible customers. The most successful rebate programs have served approximately 10% of C&I customers, including approximately 25% of large customers (customers with peak demand greater than 100–500 kW). These results are typically achieved over a period of three to seven years. Programs with high participation rates feature simple application procedures, catchy marketing materials, active involvement of equipment dealers and other trade allies, free energy audits to help customers identify conservation measures, and extensive personal marketing with an emphasis on developing a personal relationship with larger customers (26).

The most successful of these rebate programs have reduced C&I electricity use by approximately 6–7% (net savings) (29, 30) at costs to the utility of approximately $0.01 per kWh saved. The cost figures are generally based on engineering estimates and are not adjusted for the effect of free riders. Even programs that pay high rebates generally cost the utility less than $0.02–0.03 per kWh (26).

In the residential sector, results vary widely from program to program depending on how efficient an appliance must be to qualify and on how effectively the utility markets the program. If eligibility levels are too low, then a high proportion of available models qualify for rebates, which results in high gross participation rates, high free riders, and low savings per rebate (due to the influence of free riders and to the fact that eligible appliances are only slightly more efficient than the average appliance). These problems have plagued a number of appliance rebate programs (31).

As a corollary, greater success follows stricter eligibility levels and strong marketing efforts. For example, New York State Electric and Gas (NYSEG) conducted a major refrigerator rebate experiment in 1985–1986. Program eligibility was limited to the most efficient 25% of models then offered by the industry. Different marketing and rebate strategies were employed in different regions. Participation rates (as a percent of refrigerator purchases during the program) were 15% in a no-treatment control area, 35% in an information and advertising-only area, 49% in a $35 rebate area, and 60% in a $50 rebate area. Dealer cooperation and promotion of efficient models was higher in the rebate areas and was considered critical to achieving high levels of participation (32).

Research on C&I rebate programs also indicates that marketing, educational efforts, and rebate level all have an important influence on participation rates and savings (26, 33). Also, program eligibility levels have a strong effect on free-rider levels. When measures with high current market shares and/or with rapid payback periods are promoted, free riders tend to be high; when products with low market shares and/or less rapid payback periods are emphasized, free riders tend to be low (26, 34). However, while utilities generally strive to minimize free riders, if the cost of reducing free riders is high (either in terms of monetary cost or in reductions in participation rates), even programs with high levels of free riders may be cost-effective to the sponsoring utility.

Rebate programs have proven most effective at promoting basic lighting and equipment improvements. Most rebate programs currently in operation have devoted limited or no attention to promoting advanced technologies or to promoting "system" improvements (i.e. efficiency improvements that involve the interaction of multiple pieces of equipment) (26).

The more successful rebate programs combine moderate participation levels and moderate savings per customer to reduce utility peak demand and electricity sales by approximately 1% per year. There are limited indications that after several years of aggressive program promotion, participation levels from rebate programs may drop off (26). Further research is needed in this area.

LOAN PROGRAMS Loan programs have only been offered by a few utilities. Side-by-side comparisons with rebate programs offered by the same utilities show that most customers prefer rebates. For example, both Wisconsin Electric and Puget Sound Power and Light offer C&I customers a choice between a zero interest loan or a rebate that is approximately equivalent to the interest subsidy on the loan. In both programs more than 90% of the participating customers have chosen rebates instead of loans (P. Clippert, Wisconsin Electric and S. France, Puget Power, personal communications). Comparisons of residential loans versus grants have reached similar conclusions (35). However, the use of loans by some customers indicates that loans can be useful for a minority of customers who do not have sufficient cash to finance conservation improvements.

PERFORMANCE CONTRACTING PROGRAMS Performance contracting programs generally rely on energy service companies (ESCOs) to provide services to customers. The ESCOs receive payments from the utility for each kWh or kW they save. Left to their own devices, most ESCOs will choose to concentrate on the largest customers and the most lucrative energy-saving measures (particularly lighting and cogeneration) (36, 37; S. Murphy, Boston Edison, personal communication). Limited side-by-side comparisons indicate that other program approaches can achieve greater participation than ESCO-based programs (38). Most utilities that offer or have offered performance contracting programs have either phased-out these programs or chosen to complement them with other types of programs. However, several performance contracting programs that pay ESCOs high incentives, such as those offered by Boston Edison and Commonwealth Electric, have achieved significant energy savings. These programs are generally more expensive than other types of utility-operated programs promoting the same measures (26).

COMPREHENSIVE DIRECT INSTALLATION PROGRAMS Comprehensive programs generally provide one-stop shopping to the customer, including audits, arranging for measure installation, financing assistance (loans or grants), and sometimes operations, maintenance, and other follow-up services. These programs are designed for customers who lack the time, money, and/or expertise to identify and implement conservation projects on their own. Comprehensive programs can achieve higher participation rates than other program approaches used to date, although many of the most successful programs have only been operated on a highly targeted basis. Participation rates of 50–90% have been reported (26).

Comprehensive programs can also achieve higher savings than rebate programs. In the C&I sectors, savings estimates for six multiple end-use comprehensive programs ranged from 10 to 26% (all but two of these estimates were based on engineering data) (26, 30). In the residential sector, net savings of 10–15% have been achieved (39, 40). While comprehensive programs can achieve high participation and savings, these results come at a price—comprehensive programs typically cost utilities $0.02–0.04 per kWh saved in the C&I sectors (assuming a 10-year measure life) and $0.04–0.06 per kWh in the residential sector—a price below the long-term avoided cost of many utilities, but above the cost to a utility of a typical rebate program (41). However, when customer costs are included in the analysis, rebate program costs per kW and kWh begin to approach comprehensive program costs, because customers pay a higher share of measure costs in a typical rebate program than in a typical comprehensive program.

At this time, full-scale comprehensive programs have only recently started up, so a determination of how well comprehensive programs perform on a large scale remains to be seen.

BIDDING PROGRAMS In the past few years, there has been considerable interest in bidding programs where utilities request proposals from outside parties to supply demand-side and/or supply-side resources. Successful bidders are selected on the bases of price and other factors. The purpose of bidding programs is to let the market determine the price of new resources and the proper mix of program efforts, including the mix between demand- and supply-side resources and/or the mix of utility-sponsored programs relative to the efforts of non-utility parties. In some bidding programs, bids are limited to specific sectors (e.g. C&I) or end-uses (e.g. lighting); in other programs, bids for any sector or end-use can be submitted.

Actual experience with demand-side bidding programs is limited, although the number of DSM bidding programs is growing each year (42). Initial experiences indicate that bids are primarily for large C&I projects—residential and small C&I bids have been limited. The majority of demand-side bids have been submitted by energy service companies, although some bids have been submitted by large C&I customers (43) and by local architecture/engineering firms and equipment vendors (42). Indications thus far are that these programs can achieve significant energy savings. For example, by the end of 1991, Central Maine Power had signed contracts totaling 4.6% of its peak demand through its Power Partners and Efficiency Buyback programs (J. Linn, Central Maine Power, personal communication). Bidding programs, by definition, cost less than utility avoided costs (because bid prices are capped at avoided costs), although there is a tendency for bids to approach utility avoided costs. For example, a review of nine bidding programs found utility costs per kWh of $0.025–0.068 (42).

Goldman & Hirst (44) end their recent analysis of demand-side bidding programs by noting that early experiences indicate that such programs may have a limited role to play in a utility's overall demand-side management strategy owing to (*a*) the limited development of the energy services industry in the United States, (*b*) high transaction costs in certain sectors (e.g. residential and small commercial), and (*c*) the inappropriateness of bidding mechanisms for various types of programs (e.g. design assistance for new construction and other informational programs). Thus, it appears bidding programs represent only one part of a comprehensive package of demand-side management programs.

DISCUSSION From this review of program experiences, a number of important lessons emerge:

1. Information programs generally result in only limited participation rates and energy savings. However, information programs can be useful complements to other program approaches—the combination of information plus financial incentives generally results in higher participation and savings than information or incentives alone.
2. Different program approaches fill different niches. Rebate programs can be used successfully to promote efficient equipment at a moderate cost to the utility. However, rebate programs generally only reach a minority of customers and have not been very effective at promoting improvements involving the complex interactions of multiple pieces of equipment. Loan and performance contracting programs can be useful for the minority of customers who lack capital to finance conservation improvements. Performance contracting and bidding programs are also useful for utilities who do not want to operate programs on their own. However, these

program approaches require extensive administration and oversight by the utility, and are apt to be costlier than utility-managed programs. Comprehensive direct installation programs can achieve higher participation rates and savings per customer, but generally at a higher cost to the utility than information, rebate, and loan programs. This approach may be particularly suitable for serving hard-to-reach customers (e.g. low-income residents and small C&I customers) or for utilities with capacity needs in the short- and medium-term. The relative strengths and weaknesses of the different program types are summarized in Table 2.

3. Marketing strategies and technical/construction support services have a large impact on program participation and savings. Personal one-on-one marketing strategies are particularly effective. Equipment dealers, contractors, and design professionals can be important allies in promoting programs. In designing programs, it is important to keep customers' needs in mind and to make sure that marketing materials and program participation procedures are easy for customers to understand.
4. All other things being equal, financial incentives tend to increase program participation and savings.

Utility-Level Results

A recent analysis published by EPRI estimates that in 1990 DSM programs (including both energy-efficiency and load-building programs) saved a total of 32,955 GWh, and reduced summer peak demand by 19.3 GW and winter peak demand by 14.8 GW. These savings, which result from DSM activities throughout the 1980s, represent 1.1% of 1990 GWh sales, 3.6% of summer peak demand, and 3.0% of winter peak demand (45).

A review of recent efforts by six of the most active utilities in the DSM field indicates that significantly higher savings can be achieved. Table 3 summarizes the DSM savings achieved in recent years by these utilities, which have operated DSM programs for periods of 3–6 years. Cumulative kW savings are beginning to exceed 5% of peak demand and cumulative kWh savings are topping 5% of electricity sales. While the kW savings of these utilities as a percentage of peak demand are only modestly higher than those of the utility industry as a whole, the kWh savings as a percentage of electricity sales are approximately a factor of five higher. This gap between the average and the best utilities may grow further, since the most aggressive utilities are now achieving kW and kWh savings in excess of 1% per year. If these savings rates can be sustained for 10 years, the estimates of achievable DSM potential discussed previously look reasonable.

The efforts of these utilities generally can be distinguished by a number of important attributes:

Table 2 Summary of strengths and weaknesses of different program approaches

	Number of customers targeted	Number of customers served per year	Participation rate	Savings per customer	Utility cost per kWh
Information	high	moderate	low	low	varies
Load management	high	moderate	moderate	moderate–high (kW savings only)	low
Rebate	high	moderate	low–moderate	moderate	low–moderate
Loan	moderate	low	low	moderate–high	moderate
Performance contracting	moderate	low–moderate	low–moderate	moderate–high	moderate–high
Comprehensive/direct installation	moderate (can be high over long-term)	moderate	high	high	moderate–high
Bidding	varies	varies	unclear	varies	moderate–high

1. Top management commitment—Senior company officials actively support DSM efforts and transmit this commitment to staff.
2. Skilled staff—DSM departments are filled with smart, capable staff who are innovative and willing to adapt to new information.
3. Substantial investments—DSM budgets totaling 2-6% of gross revenues are common in utilities with the highest DSM savings (see Table 3).
4. Broad-based program offerings—DSM programs target each of the major sectors (residential, commercial, and industrial) and each of the major end-uses (lighting, cooling, etc) within each sector.
5. Willingness and ability to work actively with customers.
6. Pressure or encouragement from utility commissions and intervenor organizations to pursue DSM initiatives successfully.

A CRITIQUE OF CURRENT DEMAND-SIDE MANAGEMENT EFFORTS

If utilities are to achieve savings of 10% or more in the long term from DSM programs, then simple mathematics shows that participation rates of 50% or more and savings per customer of 10–30% are needed. Some utilities and programs are on track for reaching these targets, but the average utility and the average program are not this far along. Furthermore, even some of the more successful efforts and programs face potential problems, which must be surmounted if savings rates achieved to date are to be sustained. Among these problems are:

1. Over-reliance on traditional program approaches;
2. Lack of a long-term perspective in planning and operating programs;
3. Inadequate attention to "lost opportunity" measures;

Table 3 DSM savings and expenditures of selected utilities

Utility	Period	DSM savings as a % of 1989 peak demand and sales: Cumulative over period kW	Cumulative over period kWh	1991 kW	1991 kWh	1990 DSM expenditures as a % of gross revenue
Central Maine Power	1985–90	4.6	5.8	1.6	2.1	3.8
Commonwealth Electric	1988–90	1.9	4.7	1.9	2.3	5.2
Eastern Utilities	1988–90	2.1	1.7	1.7	0.9	1.5
Long Island Lighting Co.	1987–90	7.2	1.7	1.3	0.7	1.5
New England Electric	1987–90	4.1	1.9	1.2	0.7	4.1
Wisconsin Electric Power	1987–90	4.0	3.3	1.5	1.2	4.3

Source: (22)

4. Lack of coordination between utility programs and government-enacted codes and standards;
5. Poor coordination between utilities;
6. A shortage of industrial DSM programs;
7. A shortage of skilled staff, contractors, and equipment;
8. Inadequate attention to program evaluation;
9. Inattention to DSM measure persistence;
10. Regulatory processes that impede DSM implementation.

These problems, and efforts to rectify them, are discussed below.

Over-reliance on Traditional Program Approaches

The most common types of utility DSM programs are information, rebate, and load management programs (2). Unfortunately these types of programs usually have low participation rates and savings per customer, for reasons including inadequate marketing, limited technical assistance, limited measures included in programs, and low incentives (26, 33, 41).

Marketing strategies and technical/construction support services influence program participation and savings greatly. Many utilities rely on direct mail marketing pieces and bill inserts—strategies that generally have only limited impact. More effective strategies, such as personal one-on-one and intensive community-based marketing strategies (going door-to-door in a targeted community), are employed less often.

Marketing materials and program participation procedures are often difficult for customers to understand—simpler materials and procedures can make programs more attractive to customers. For example, many utilities operate separate programs for each type of DSM measure (e.g. a lighting program, a motor program, etc). Customers are confused by a barrage of program solicitations. When all measures are packaged into a limited number of programs, customer confusion is reduced, and savings can increase because customers are more likely to find appropriate measures and/or to implement more than one measure.

Program designs and marketing strategies are often not adapted to the needs of particular markets (e.g. new construction, remodeling, replacement of worn-out equipment, or retrofit of inefficient but functioning equipment) and decision-makers (e.g. customers, equipment dealers, architects, engineers, and developers). These markets and decision-makers vary in the measures they will consider, the timing of decisions, and the factors that influence decisions. By recognizing and targetting these different markets, utilities can increase program participation rates.

Technical assistance and construction support services encourage and assist customers to participate in a program, but are missing from most programs. These services should be matched to the type of customer and to other services offered. Small customers generally require simple analyses and extensive assistance implementing measures. Large customers often need less assistance. In-depth technical assistance, such as providing detailed audits, is sometimes worthwhile if financial incentives and other services are available, making customers likely to implement recommendations; however, if no financial incentives are available, it is usually not cost-effective to provide such in-depth technical assistance (26).

Financial incentives tend to increase program participation and savings, yet many utilities are still expecting high participation from limited incentives. In many cases, incentive levels should be increased. For example, the New England Electric System (NEES) raised incentives on its motor rebate program from less than 50% of full motor price to nearly 100% of motor price (in both cases the customer must pay installation costs). This change, introduced together with simplifications to the application form, increased the monthly participation rate approximately fourfold (46).

Low savings are due in part to the limited number of measures for which rebates are generally available. In the C&I sectors, rebates are commonly restricted to basic lighting improvements and more efficient motors and cooling equipment. Rebates are usually not available for many other energy-saving measures such as variable-speed motor drives, industrial process improvements, improved controls for heating and cooling systems, and more efficient refrigeration systems. Furthermore, many programs, in an effort to maximize short-term savings, concentrate on first-generation efficiency measures (e.g. reduced-wattage fluorescent lamps) with which customers are already familiar. By promoting advanced energy-saving technologies instead (e.g. thin-diameter "T8" lamps and lighting controls), greater savings can be achieved than with first-generation technologies alone.

Rebate programs often ignore the synergisms among measures that can increase measure savings and decrease measure costs. A few utilities provide bonuses when groups of measures are installed at the same time—a practice that should be offered by more utilities. However, many customers can benefit from additional assistance and encouragement to identify and install the optimum package of efficiency improvements.

Thus, while rebate programs may be a useful start to DSM efforts, if cumulative savings are to top 10%, rebate programs will have to be complemented with other program approaches with higher participation rates and savings. Comprehensive programs show much more promise in this regard. However, efforts to date have been primarily pilot and limited-scale applications; comprehensive approaches need to be implemented in large-scale efforts before their usefulness is proven. In addition, other new, creative approaches need to be developed and tried. Some examples are discussed in the next two sections.

Long-Term Perspective in Planning and Operating Programs

Most utility DSM programs are planned and operated one year at a time—there is no long-term vision. Programs should be based on long-term plans to transform the market to the most efficient equipment and practices that are possible and cost-effective.

An example of taking a long-term approach to DSM is an effort by the Bonneville Power Administration (BPA) and the Northwest Power Planning Council (NWPPC) to improve the efficiency of new homes in the Pacific Northwest. In the early 1980s, BPA and NWPPC developed Model Conservation Standards (MCS) that specified substantial improvements in insulation, equipment efficiency, and infiltration reduction relative to prevailing construction practices in the region. Homes built under the MCS use 28–40% less energy for space heating than do pre-MCS homes (47). These standards were then promoted through two programs—a "Super Good Cents" program that offered training, advertising assistance, and financial incentives to builders who built to MCS standards voluntarily, and an "Early Adopters" program that offered technical and financial assistance to municipalities who adopted MCS requirements as part of mandatory local building codes. By 1992, more than 80% of new electrically heated homes built in the BPA service area are subject to MCS building code requirements (T. Eckman, Northwest Power Planning Council, personal communication).

Lost Opportunity Measures

At the time a home or office building is constructed, many conservation measures can be installed for only an incremental cost beyond standard construction practices. To retrofit these measures later is usually much more expensive and sometimes impossible, which is why new-construction conservation opportunities are often referred to as "lost opportunity" resources. Building renovations, remodeling, and situations when long-lived equipment (e.g. ballasts, motors, and cooling equipment) are being replaced are other examples of potential lost opportunities.

Lost opportunity situations permit substantial efficiency gains at modest cost, yet most utilities pay little attention to these markets. To capture these opportunities requires developing specific programs or program components for new-construction, renovation, and equipment-replacement situations. An important element of these programs is on-going market research to identify customers who are about to make lost-opportunity decisions. These decisions are generally made within a narrow window of time, so to capture efficiency gains, the utility has to be able to offer quickly a wide-range of assistance and inducements to convince customers to develop the most-efficient designs and install the most-efficient equipment that are viable. For example, Green Mountain Power has an equipment replacement and remodelling program that features rebates to equipment vendors for sales of efficient equipment and design assistance and incentives to improve the efficiency of remodeling jobs. Special marketing efforts identify eligible customers and refer them to either the equipment replacement or remodeling tracks of the program (48).

Coordination Between Utility Programs and Codes and Standards

Even improved utility programs cannot achieve all of the cost-effective savings that are technically achievable. Some customers will always choose not to participate in a program. Building codes, equipment efficiency standards, and other similar policies can achieve additional savings beyond those achieved by utility programs. For example, the California Energy Commission's estimate of statewide conservation and load management savings for 1987 totaled 5100 MW, of which 50% were due to utility programs, 47% to building code improvements and appliance efficiency standards, and the remainder to miscellaneous efforts (49).

Utilities can and should support building codes and efficiency standards, where such standards are cost-effective for most of their customers. For example, utilities in Washington State were instrumental in recent efforts to strengthen the Washington State building code. Standards and codes likely to be proposed in the 1990s include improved energy standards for residential and commercial buildings, and strengthened efficiency standards for fluorescent ballasts, residential appliances, and commercial heating, ventilation, and cooling (HVAC) equipment. In addition, utilities can aid efforts to improve compliance with these codes and standards by sponsoring training programs for building designers and code officials and co-funding enforcement efforts. For example, the Bonneville Power Administration funds a number of code training and enforcement projects in recognition of the fact that without their support, energy codes receive low priority from code officials (50).

Utilities can also encourage equipment purchases and construction practices that exceed code requirements, thereby helping to make additional improvements to codes and standards possible. An example of this approach is the "Golden Carrot" Refrigerator program now being planned by several utilities. This program offers incentives to refrigerator manufacturers to design and produce refrigerators substantially more efficient than those on the market. A major objective of this program is to demonstrate that high refrigerator efficiency levels are technically feasible, so that these efficiency levels can become the basis for 1998 revisions to federal refrigerator efficiency standards (51).

Coordination Among Utilities

Most utilities design and operate DSM programs in relative isolation from the DSM efforts of other utilities. While there is some sharing of information, rarely does this coordination extend to coordinated or jointly operated programs. A few examples of improved coordination are emerging, however. For instance, the Northeast Region Demand-Side Management Data Exchange (NORDAX) sponsors a database of DSM program results of member utilities, and offers periodic seminars and information-sharing meetings for member utilities. Coordination on program eligibility criteria is illustrated by the Appliance Efficiency Group—a group of utilities in the western United States that have developed common eligibility criteria and installation requirements for residential water heater rebates and showerhead retrofit programs (A. Gordon, Washington State Energy Office, personal communication).

Jointly operated programs have the potential to reduce administrative costs and customer confusion caused by the operation of multiple DSM programs in the same geographic area. This coordination can take the form of cooperation among adjoining electric utilities, or among electric, gas, and water utilities serving the same geographic area. An example of the former is the Energy Crafted Home program developed jointly by four electric utilities in Massachusetts (52). Since builders can and do build homes in several different utility service territories, such a multi-utility program is easier for builders to understand and use. An example of the latter is a program for direct installation of low-cost electricity-, gas-, and water-saving measures, which is jointly funded by United Illuminating, Southern Connecticut Natural Gas, Bridgeport Hydraulic, and the New Haven Water Company (53).

Industrial Demand-Side Management Programs

While most utilities design programs to serve both commercial and industrial customers, many utilities are finding that combined C&I programs primarily promote basic lighting, HVAC, and motor improvements, and that only limited industrial process improvements are being implemented. For example, 44% of Wisconsin Electric's kWh sales are to industrial customers (54), but only about 24% of kWh savings achieved by their 1991 Smart Money program are due to industrial DSM measures (T. Hawley, Wisconsin Electric, personal communication). These problems have led large industrial customers to object to utility DSM efforts, contending that industrial customers are subsidizing DSM investments of residential and commercial customers. Furthermore, some large industrial customers are concerned that they are subsidizing DSM investments of other industrial customers with whom they compete (55).

Barriers to industrial customer participation in conservation programs include (*a*) program marketing materials that emphasize commercial conservation measures and thereby provide the impression that the program has little to offer industrial customers, (*b*) concerns about shutting down process lines in order to install new equipment (the value of a single day of production can equal an entire year of energy savings), and (*c*) the fact that most industrial process improvements require engineering analysis and supervision, but many plants and most utilities lack staff with the necessary skills or time to undertake such projects.

To overcome these problems, creative programs that target industrial process improvements are needed. Examples of successful efforts include BC Hydro's Compressed Air program, Wisconsin Electric's Smart Money for Business program, and BPA's Conservation/Modernization Program. The BC Hydro program has served more than 60% of eligible customers by identifying a single efficiency measure (repair of compressed air leaks) and offering free leakage tests and encouragement to repair leaks that are located. The Wisconsin Electric program offers a combination of prescriptive-measure rebates and custom incentives for measures designed by customers. Approximately 30% of industrial customers have participated in the program, reducing the utility's sales to the industrial sector by 2.5% at a cost of less than $0.02 per kWh. The BPA program provides incentives for large aluminum smelters (who account for more than 90% of BPA's industrial sales) to implement conservation measures. Eligible customers were heavily involved in the program design process. As a result of this and other factors, 10 out of 10 eligible customers elected to participate, and the program has reduced industrial electric sales by nearly 4% (56).

In addition to designing programs well, utilities need to work more with industrial customers so that customers support, rather than oppose, DSM efforts. Possible approaches to developing this support include involving industrial customers actively in program design, and allocating DSM costs by customer and rate class so that large industrial customers do not subsidize DSM programs for residential or small industrial customers (or visa versa).

As a result of programs and efforts such as these, a number of utilities have brought industrial-sector participation in DSM programs up to levels in other sectors. For example, in 1989, 21% of NEES's revenues came from industrial customers and 21% of DSM expenditures went to industrial customers (T. Stout, NEES, personal communication).

Shortage of Skilled Staff, Contractors, and Equipment

As DSM programs expand, a growing number of skilled people are needed to plan, run, and evaluate the programs, and to design, specify, and install DSM measures. In addition, large quantities of efficient equipment are needed. However, in recent years the demand for these people and this equipment has sometimes outstripped supply. For example, experienced DSM professionals receive calls from "head hunters" on a regular basis, and utilities and consulting firms often hire staff without DSM experience who must learn on the job. Similarly, the supply of architects, engineers, lighting designers, and equipment installers who are experts in energy-efficient design and construction is sometimes inadequate for the demand. To help deal with these problems, training courses are offered by two new nonprofit organizations—the Association of Demand-Side Management Professionals and the Demand-Side Management Training Institute—and several universities have begun new degree programs in lighting design.

Shortages of efficient equipment have also hampered DSM efforts. For example, due in large part to heavy sales caused by utility DSM programs, there is currently a world-wide shortage of compact fluorescent lamps and waiting periods for electronic ballasts have sometimes exceeded three months. In an effort to assist these markets, the Electric Power Research Institute and the Lighting Research Center have jointly surveyed utilities and manufacturers to collect information on future program and manufacturing plans, so that utilities and manufacturers can better understand each other's plans, and thereby adjust their own plans accordingly (57). They plan to repeat this survey periodically.

Nationwide, only several dozen energy service companies (ESCOs) have experience delivering DSM services in a bidding situation. As DSM solicitations have increased, the experienced ESCOs have become booked, resulting in limited response to solicitations. Very recently however, there have been a number of new entrants into the DSM bidding sweepstakes, with the result that several of the most recent solicitations have received more than 30 DSM bids, up from the 8–15 bids received in response to earlier solicitations (42).

A final problem is that when personnel and equipment are in short supply, "fly-by-night" contractors and equipment suppliers enter the market. For example, in response to shortages of compact fluorescent lamps, several products with high failure rates have entered the market. Inexperienced lighting installers whose installations violate many basic rules of lighting design have also entered the market. Utilities have responded to these problems with quality-control efforts such as pre- and post-installation inspections, training seminars for installers and utility staff, and development of equipment specifications.

Program Evaluation

As utilities come to rely increasingly on demand-side resources to meet energy and capacity needs, they become interested in careful documentation of program savings and cost-effectiveness. However, many DSM programs have yet to be evaluated, and the quality of some evaluation efforts leaves much to be desired. Many evaluations rely on engineering estimates of savings, but engineering estimates are only as good as the formulas employed and the assumptions used in the calculations. Unfortunately, many of the formulas do not allow for factors known to affect energy use (for example rooms that are not heated), and the assumptions used are often erroneous. As a result, engineering estimates often overestimate energy savings. This problem is particularly acute for residential retrofit programs and commercial lighting programs for small customers. For residential appliance and new-construction programs, and multiple-measure C&I retrofit programs directed at large customers, on average, engineering estimates have been reasonably accurate (58). In most cases impact evaluation studies, which use statistics to analyze the energy bills of program participants before and after the program, and compare these results to a control group of nonparticipants, provide more accurate estimates of energy savings than engineering estimates.

Furthermore, while most utilities track direct program costs (e.g. rebates), most do not track indirect costs such as marketing costs and staff time (59). As a result it is difficult to assess program cost-effectiveness with accuracy.

In the past few years, evaluation has received increasing attention. Utility commissions are requiring utilities to evaluate programs carefully (60), new manuals on evaluation techniques have been published and widely distributed (61, 62), and conferences on evaluation techniques and results have been well attended (for example, an August 1991 conference on DSM evaluation drew 430 people—G. Ettinger, personal communication).

Demand-Side Management Measure Persistence

DSM cost-effectiveness analyses usually assume that measures will save energy for many years—assumptions of 10–20-year measure lives are common. However, like power plants, in order to function for 10–20 years, DSM measures must be properly installed and maintained. A few utilities are beginning to study the issue of DSM measure persistence, and are discovering that while most DSM measures do persist for many years, some measures do not.

For example, evaluations of institutional building efficiency programs in Utah and the Pacific Northwest have found that some energy-efficiency measures, such as controls, are not properly maintained, and as a result, energy savings have declined from initial levels (63, 64). Similarly, NEES found that 20% of the compact fluorescent lamps installed through its Energy Fitness program had been removed, primarily because their light output did not match the lamps they replaced (40; C. Granda, NEES, personal communication).

To address these problems, some utilities have revised program procedures to improve the installation, commissioning, and maintenance of DSM measures. For example, Pacific Power & Light now promotes commissioning procedures and on-going maintenance plans for their commercial new construction program (65). NEES has developed criteria and training programs to ensure that the light output of compact fluorescent lamps installed through its programs are adequate for each task (C. Granda, NEES, personal communication). Such procedures need to be instituted throughout the DSM industry in order to make sure that DSM savings are there when they are needed.

Regulatory Processes

While regulator interest in DSM is one of the major factors that have led utilities to pursue DSM programs, some aspects of the regulatory process inhibit DSM progress.

First, and most importantly, traditional regulatory practices link utility income, and hence profits, to sales. Thus, even when DSM programs benefit ratepayers by reducing resource costs, utility shareholders may not benefit (66). As a result, many utilities are reluctant to embrace DSM. In order to overcome this problem, at least four states (California, Maine, New York, and Washington) have taken steps to decouple utility profits from sales. In addition, at least 20 states have adopted some type of incentive mechanism to provide shareholders with direct financial incentives for successful implementation of DSM programs. Typically these incentive mechanisms provide shareholders with a small portion (approximately 10%) of the financial benefits attributable to DSM programs (67). Initial results from these efforts indicate that utilities that receive these incentives do in fact significantly increase their DSM efforts (68).

Second, a number of commissions have begun to micro-manage DSM efforts and/or to stifle DSM efforts with voluminous reporting requirements. For example, in 1991, NEES had to submit 21 different filings on its DSM efforts (E. Hicks, NEES, personal communication). As a result, staff have less time to plan and implement programs. While some reporting requirements and oversight are essential, since many utilities have been reluctant to pursue DSM initiatives, commissions should take care not to be overzealous in their oversight role.

CONCLUSIONS

Utility DSM programs have the potential to reduce electricity sales and peak demand by 10–20% over the next 10–20 years. Substantial additional savings are possible as a result of market forces, codes, and standards. Over the past decade much has been learned about how to structure and promote programs in order to achieve substantial energy and dollar savings. However, a number of problems have also arisen that must be addressed if DSM programs are to achieve their full promise. Fortunately, efforts to address these problems have begun.

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