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REVIEW OF DEMAND-SIDE DATA NEEDS FOR LEAST-COST UTILITY PLANNING

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Abstract—Least-cost utility planning is a new way for utilities and state regulatory commissions to assess consistently a variety of demand and supply resources that cost-effectively meet customer energy-service needs. This new planning paradigm (a) explicitly includes conservation and load-management programs as energy and capacity resources; (b) includes consideration of environmental and social factors, as well as of direct economic costs; (c) involves public participation; and (d) includes careful analysis of the uncertainties and risks posed by different resource portfolios and by external factors. The relative paucity of data on demand-side resources, particularly when compared to the information available on supply resources, poses a significant barrier to integrating these options into utility resource plans.

In this study, we briefly compare the data and assumptions available on supply resources with those available on demand-side resources. We then discuss the types of data that are needed to assess existing patterns and trends in electricity use (baseline data), the costs and performance of demand-side technologies, and the effects of demand-side programs. Our analysis suggests that evaluation of program effects is the area with the greatest need for additional attention.

INTRODUCTION

In recent years, electric utilities have operated and planned in an environment characterized by volatile energy markets and considerable uncertainty about future load growth, fossil-fuel prices and availability, and the costs and construction times for different kinds of resources. Between 1972 and 1984, utilities cancelled nearly 200 power plants, resulting in losses of tens of billions of dollars. Today, electric utilities operate in a rapidly changing economic and political environment and face challenges from independent power producers, as well as a public increasingly concerned about the environmental consequences of electricity production. As a consequence, many regulators and utilities have shown great interest in new approaches to planning and decision-making, a process called least-cost utility planning (LCUP). About 17 states have adopted LCUP strategies, while least-cost planning approaches are under development in another 20 states.[1]

Least-cost planning involves consistent assessment of various demand and supply resources to meet customer energy-service needs at the lowest economic and social cost. Least-cost utility planning is important to utilities, their customers, and public utility commissions (PUCs) primarily because of problems that arose with traditional planning methods.[2–5] These problems included a narrow focus on central-station power plants, limited consideration of uncertainty, and little public involvement.

To assess a variety of energy and capacity resources, utilities require comprehensive and accurate data on these resources. Unfortunately, a serious imbalance exists between the data available on supply resources and those available on demand-side management (DSM) resources. The amount and variety of data on traditional generation resources is almost overwhelming. Forms completed by utilities for the Energy Information Administration, Federal Energy Regulatory Commission, and North American Electric Reliability Council provide a wealth of detail on the construction time and cost, fixed and variable operations and maintenance costs, heat rate (a measure of the efficiency with which the fuel is converted to electricity, expressed in Btu/kWh), and capacity factor for individual power plants. For

Table 1. Data requirements of the Federal Energy Regulatory Commission Form 1: Electric Operation and Maintenance Expenses.

Power Production Expenses (63 entries)
Transmission Expenses (17 entries)
Distribution Expenses (21 entries)
Customer Accounts Expenses (5 entries)
Customer Service and Informational Expenses (4 entries)
Supervision
Customer Assistance
Informational and Instructional
Miscellaneous Customer Service and Informational
Sales Expenses (4 entries)
Supervision
Demonstration and Selling
Advertising
Miscellaneous Sales
Administrative and General Expenses (15 entries)

example, the Federal Energy Regulatory Commission Form 1 includes 63 entries on the costs to operate and maintain power plants and not a single identifiable entry on the costs to operate energy-efficiency and load-management programs (Table 1). Similarly, the Electric Power Research Institute (EPRI) Technical Assessment Guide has provided cost and performance data on supply-side technologies for over a decade, while end-use technologies were not addressed until recently.[6]

This imbalance was also identified in a 1986 survey of utilities and PUCs, which asked about critical needs related to integrated resource planning.[7] The report concluded that most utilities lack information on the cost, performance, and energy and load effects of demand-side options, as well as on the market-penetration rates and energy and peak reductions that could be achieved with utility DSM programs. Utility needs for demand-side data are a consequence of the growth in number and intensity of utility DSM programs. A 1985 EPRI survey identified almost 900 DSM projects at 300 utilities, involving more than 5.5 million customers.[8]

The quality of data currently used in least-cost planning needs to be significantly improved, especially on the demand side.[9] Since the early 1980s, EPRI has sponsored much DSM research, including surveys of utility DSM activities, analytical and planning tools, and information on end-use markets and technologies.[10] In spite of this progress, reviews of current utility DSM plans reveal important deficiencies, such as the lack of available data for certain end uses and sectors, limited experience in screening and interpreting DSM data, and lack of guidelines to ensure quality control.[11] Public utility commissions share responsibility with utilities to ensure that DSM programs are carefully planned and evaluated, so that reliable data on the cost and size of resource options are available.

In this study, we review the types and quality of data used to analyze DSM resource options and identify areas where additional work would help reduce uncertainties about DSM technologies and programs. The following ingredients must be combined to quantify the cost and size of such resources: (a) baseline data on the efficiency and utilization patterns of end-use systems in the existing stock, (b) a comprehensive data base on costs and performance (including long-term persistence) of energy-efficiency and load-management technologies, and

(c) data on customer acceptance of and participation in different types of utility DSM programs, and on utility costs to run these programs. We discuss these issues in the following three sections.

END-USE LOAD SHAPES AND OTHER BASELINE DATA

Utility planners require detailed data on energy end uses and on the underlying factors affecting the structure of energy demand to confidently incorporate DSM options into the utility's resource mix. The requirements for end-use and market research data have increased as utilities have paid more attention to developing DSM options.[9,12] The traditional utility planning process required that the utility predict future energy demand at an aggregate level, but not necessarily understand its components in detail. For example, prior to the development of DSM programs, a utility might develop its forecast of lighting loads based on engineering estimates of average lighting power densities, projected floorspace, and a diversity factor reflecting usage during peak periods. However, a utility designing a DSM lighting program must also have information on the type and saturation of lighting equipment (lamps, ballasts, and fixtures) and control systems as well as on customer preferences and investment criteria to reliably estimate potential savings from such a program. Market research, energy audits, and pilot programs are used to obtain such information.

Hourly loads by end use are important for assessments of DSM technology performance, market-penetration rates, and utility-system-load impacts. The Hood River Conservation Project[13] provides a good example of valuable baseline data. Information on electricity use for space heating, at different times and for different types of houses, helped to place the Hood River electricity savings in perspective (Fig. 1). Similarly, the end-use load-research data (Fig. 2) provided valuable information on baseline load shapes and electricity-use patterns for space heating, water heating, and base loads, as well as the whole-house load.[14]

However, end-use monitoring is costly and time-consuming, and the volume of data makes data management and analysis cumbersome. Thus, the key challenges in this area involve identifying ways to transfer load-research results from one location to another, and developing and disseminating information on cost-effective monitoring and analysis methods (e.g., accurate methods of disaggregating whole-building hourly loads by end use and methods of managing large data sets from continuous end-use monitoring). One way to achieve this objective would be to compile, analyze, and publish measured end-use load data from many sources. For example, a recent EPRI project compared commercial end-use intensity (EUI)

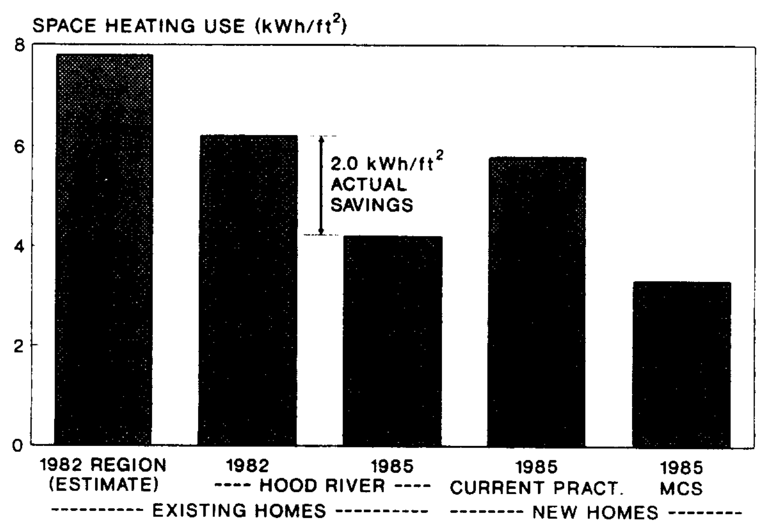

Fig. 1. Comparison of annual electricity use for space heating in single-family homes in the Pacific Northwest (Ref. 13).

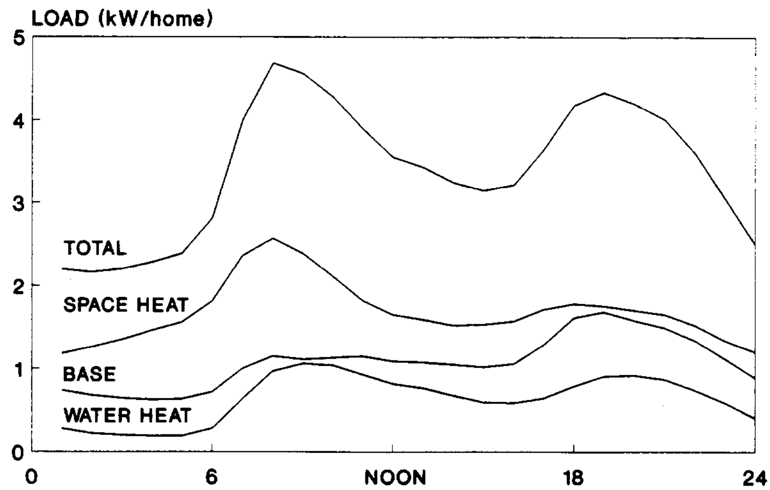

Fig. 2. Diversified household daily load shapes in Hood River, by end use, before retrofit (Ref. 14).

estimates developed by different sources and recommended methods that utilities could use to calibrate and use EUI estimates from other sources.[15] Unfortunately, none of the estimates was based on end-use metering of a statistical sample of buildings. The Electric Power Research Institute also sponsored development of "reference load shapes" for residential and commercial baseline end-uses and load shape impacts of selected DSM measures; here too, results were based on engineering simulations, rather than measured data.[16]

Recently, there has been a significant increase in utility monitoring of end-use loads in occupied buildings. For example, utilities in California have sponsored end-use metering projects of over 1000 residences.[17] Utilities have also begun to monitor large numbers of commercial buildings. The End-Use Loads and Consumer Assessment Program, sponsored by Bonneville Power Administration, collected hourly end-use data on 140 commercial buildings and 430 residences. Several other commercial monitoring projects are underway or in the planning stages in Florida, Wisconsin, and California.[18]

TECHNICAL AND ECONOMIC ASSESSMENT OF DEMAND-SIDE TECHNOLOGIES

Regulators want utilities to consider a comprehensive list of efficiency and load-management technologies, and both PUCs and utilities need credible, up-to-date cost and performance data on DSM options. Assessments of end-use efficiency and load-management technologies have been undertaken by many organizations. Most studies estimate the technical potential for savings that could be achieved by installing a comprehensive set of DSM options and represent the aggregate potential using supply curves.[19–22] Such curves show the size of the resource that is available as a function of its cost in ¢/kWh or $/kW, which can then be compared with supply options (Fig. 3). The Northwest Power Planning Council and Bonneville Power Administration adopted this framework to evaluate supply and demand options—the cost of supplying or conserving a kWh.[23] In addition to estimating the technical potential for conservation, they also develop detailed program plans. Their analysis includes an estimate of the market potential of demand-side resources, based on achievable penetrations of each measure for a given set of programs. A similar analysis was conducted for the state of Michigan.[24] The technical potential is used mainly as a yardstick to gauge the degree to which actual programs implement the full technical potential.

In addition, various organizations report on individual demand-side technologies. For example, EPRI supports an extensive research and demonstration program for heat pumps as does the U.S. Department of Energy (DOE) at Oak Ridge National Laboratory. The Department of Energy recently funded assessments of several end-use technologies, such as

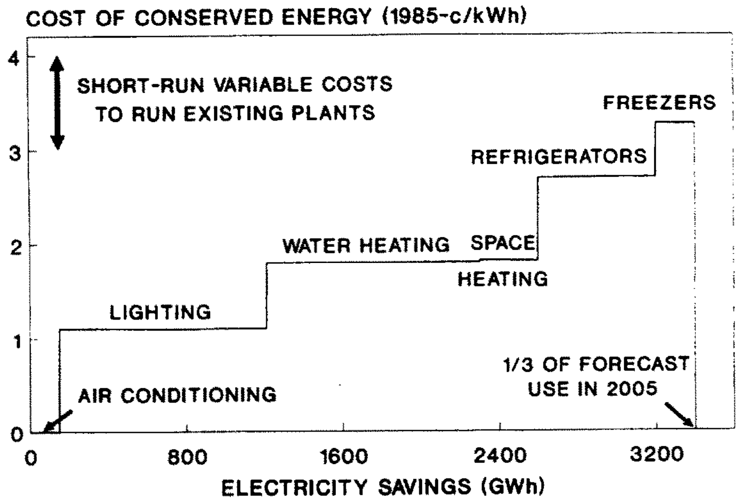

Fig. 3. Residential conservation supply curve for Michigan (Ref. 24). The cost-of-conserved-energy estimates are based on a 3% real discount rate.

lighting, motors, and cool storage.[25] However, coverage of individual end uses and technologies is still uneven.

These gaps could be bridged by establishing a comprehensive list of technologies that can be included in utility DSM plans. These technology assessments would be updated regularly (in part because of the speed of technical innovation) and would include field-performance data and comparisons of actual vs predicted energy savings. Such studies should focus on baseline data and DSM options for the commercial and industrial sectors.

ASSESSING DSM PROGRAM IMPACTS: MARKET PENETRATION, ENERGY SAVINGS AND COSTS

Most utilities report that the assessment of actual impacts from DSM programs is the area with the largest uncertainties. For example, in its initial long-range DSM plan, Niagara Mohawk stated: "with respect to all types of demand-side programs, there are major uncertainties about how much it will cost to induce a change in electricity consumption patterns. . . . This problem exists because of fundamental uncertainties about customer acceptance rates and the extent of free ridership associated with any given program, as well as other market uncertainties".[26] Market penetration, or customer acceptance, of specific technologies or progams, and the incremental load and energy impact of DSM programs are key factors in assessing the likely benefits of DSM programs. However, estimating program participation is difficult because it requires knowledge of customer investment decision making and because it requires analysis of the incremental energy-use changes that occur because of a program beyond those that would have occurred without the program.

In evaluating DSM programs, utilities use several techniques to estimate the share of "free riders", customers who would have purchased the equipment without an incentive. For example, Northern States Power recently evaluated its residential appliance rebate program, which offered rebates for the purchase of efficient refrigerators, room air conditioners, central air conditioners, heat pumps, and water heaters. Three groups of customers (participants, random sample of utility customers, and customers from another utility) were sent a mail survey that asked respondents to choose (hypothetically) between a more expensive energy-efficient appliance with a rebate, and a similar but less efficient model of the same appliance. Between 50 and 80% of the respondents said that they would have purchased the efficient appliance without the rebate, suggesting a large number of free riders.[27] On the other hand, participating dealers estimated that sales of efficient appliances increased by 3% to 19% during the first year of the program compared to the year before. Based on this evaluation, the utility decided to lower rebate levels to customers and include additional incentives to dealers, because dealers were recognized as a critical element in marketing efficient appliances.

Survey methods that use hypothetical appliance choices illustrate the practical difficulties in inferring the determinants of consumer behavior. Relying solely on the subjective responses of consumers to such questions may not be the best way to understand consumer purchase patterns, in part because purchase decisions are often made under emergency conditions. For example, Niagara Mohawk found that 60% of all customers who purchased water heaters and 40% of those who purchased refrigerators replaced a broken unit, while air conditioner sales were strongly correlated with extremely hot weather.[28]

While market penetration estimates necessarily depend on subjective judgment, the difficulties in estimating load-shape impacts are principally caused by objective data limitations, which could be overcome with additional end-use load research projects. Energy savings must be calculated relative to some baseline, which may not be well-characterized and which may change over time (e.g., because of new building standards). However, as discussed earlier, utilities are developing information on the load shape impacts of DSM measures through engineering simulation, metering, field tests of specific technologies and transferring and adjusting load shapes from other utilities.[29]

The level of financial incentive required to induce customers to participate in utility DSM programs is another key factor that affects cost-effectiveness. Program designs can greatly influence the cost of DSM measures borne by ratepayers as opposed to participants. Efficient program design can minimize adverse rate impacts. In reviewing DSM plans, it is important to be able to compare penetration rates of proposed programs with the range of participation rates achieved by other utilities that operate similar programs.

New York State Electric and Gas Corp. conducted a pilot refrigerator rebate program in which two levels of rebate and an information-only program were compared with each other and with a no-program (control) area (Fig. 4).[30] The market share of high-efficiency refrigerators reached 60% in the area with the $50 rebate compared with only 15% in the control area. Results from this pilot showed the effects of financial incentives on purchase decisions, gave preliminary indications on free ridership, and suggested ways to implement a systemwide program of appliance rebates.

A few comprehensive reviews of utility DSM programs have been conducted, targeted at specific end uses or sectors, such as utility rebate programs and residential and commercial sector programs.[31,32] In addition, a few organizations have devoted substantial resources to evaluations of their programs. Bonneville Power Administration has taken the lead in this area and conducts what is probably the most comprehensive and successful evaluations of its DSM

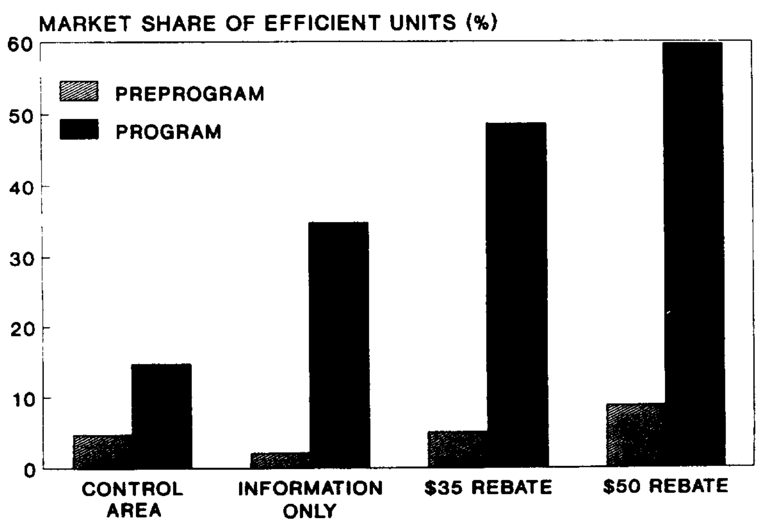

Fig. 4. Market shares of high-efficiency refrigerators before and during a pilot program run by New York State Electric and Gas Corp. (Ref. 30).

programs, information which is then used to adjust BPA's planning estimates of conservation resources.[33]

Many other utilities have evaluated their DSM programs, which are often reported at the major DSM conferences. These program-experience reports provide valuable data on customer acceptance of DSM technologies and programs, program costs, effective marketing approaches, and energy and load impacts.

Recently, these informal conference-related networks have been augmented by more formal groupings of DSM planners. For example, utilities in the Northeast recently created the Northeast Region Demand-Side Management Data Exchange (NORDAX), with a database that currently includes information on 90 DSM programs. The utilities participating in NORDAX concluded that: (a) a regional DSM database was both feasible and valuable, (b) such a project can be successful only if participating utilities commit significant human resources as well as funding for the collection of data, (c) some of the experiences gained from implementing DSM programs are transferable to other utilities, and (d) significant deficiencies still exist in the available DSM program data needed for planning, although regional databases can be used to identify these problems and target future research efforts.[34]

Our review suggests that evaluation of DSM program impacts is the area in which there is the greatest need for additional resources. Demand-side management options will be taken much more seriously by utility planners if their actual impacts can be demonstrated. One thrust of this work should be directed towards developing information exchange forums that allow utilities to share experiences in implementing DSM programs. For example, the NORDAX database includes information on market penetration rates, estimated energy and peak savings, and program costs. This information should be useful to member utilities in their program planning. This type of data exchange could be valuable in other parts of the country as well. Other approaches have also been successful: collaborative planning processes in the Pacific Northwest and New England share and compare information on DSM programs among various stakeholders. These efforts may encourage participants to develop common protocols to use in reporting DSM program impacts. Ultimately, this approach may increase the confidence that utility planners have in using DSM-program data from other utilities.

There is also a need to support researchers who collect, analyze and disseminate information on DSM programs. For example, it would be useful to expand EPRI's surveys of utility DSM programs. As part of this work, pilot and full-scale DSM program activities should be correlated with a list of available DSM technologies, to assess various program-delivery mechanisms that are being utilized for different technologies. Additional analysis is warranted of several types of DSM programs to improve coverage by end use and sector, especially industrial sector programs. Moreover, documented case studies of successful programs are useful for utilities that are initiating DSM programs. Finally, one of the biggest barriers to developing reliable estimates of the cost-effective market potential for DSM technologies is the limited understanding of the relationship between utility incentives and customer participation rates in DSM programs. A detailed understanding of end use markets and customer investment decisions is required to design programs that make optimal use of utility financial incentives.

CONCLUSIONS

Least-cost utility planning considers a much broader array of energy resources than traditional planning approaches do, including end-use-efficiency investments and load management by utilities, transmission and distribution options, alternative pricing options, and dispersed power generation. This planning process can yield enormous benefits to consumers and society: acquisition of resources that meet customer energy-service needs in ways that are low in cost, environmentally benign, and publicly acceptable. Least-cost utility planning as a planning and regulatory process can also greatly reduce the uncertainties and risks faced by utilities and PUCs. Such benefits occur because of the diversity of resources considered, public involvement in the planning process, and cooperation among interested parties.

To fully realize these benefits, a number of technical and institutional issues need further development.[35] This study focused on one key issue: the development of reliable information on the performance and costs of demand-side technologies and programs. The greater emphasis on DSM resources and the requirements of demand-side planning increase utility needs for an accurate, detailed understanding of the baseline conditions that define energy use by end use. Despite significantly increased efforts on DSM research and information dissemination, there is still a serious imbalance between the information available on supply and demand-side resource options. Many utilities believe that the uncertainties about the actual load impacts, costs, and customer acceptance of DSM programs are too high to move beyond pilot programs. Demand-side management options will be taken much more seriously by utility planners if the actual impacts of such programs can be demonstrated. Additional emphasis on DSM program evaluation, collaborative efforts among utilities and others to develop better technical and market information, plus more research to fill the important data gaps on DSM technologies and programs are all steps that will increase confidence in the benefits of DSM programs.

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