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EXECUTIVE SUMMARY

Least-cost utility planning (LCUP) is a new way for utilities and state regulatory commissions to consistently assess a variety of demand and supply resources to cost-effectively meet customer energy-service needs. This new planning paradigm differs from traditional utility planning in at least four ways: (1) it explicitly includes conservation and load-management programs as energy and capacity resources, (2) it considers environmental and social factors as well as direct economic costs, (3) it involves public participation, and (4) it carefully analyzes the uncertainties and risks posed by different resource portfolios and by external factors.

Many utilities and state commissions, supported by their research institutes and trade associations, have developed new planning tools and data, written least-cost planning regulations, prepared least-cost plans, and conducted research projects to support these efforts. Since 1986, the U.S. Department of Energy (DOE) has managed a small Least-Cost Utility Planning Program (with an annual budget of about $1 million). The program began with a review of existing activities, interests, and needs among utilities, commissions, research organizations, and other groups. Subsequently, DOE began funding a variety of projects at utilities, consulting firms, public utility commissions, and national laboratories. These projects focus on the planning process, alternatives to traditional rate regulation that would encourage least-cost planning among utilities, bidding procedures for demand-side resources, improved planning methods, development of additional data on demand-side technologies and programs, and technology transfer. DOE's limited budget requires it to play primarily a catalytic role, working closely with other organizations.

This study reviews recent progress in least-cost planning throughout the U.S. and identifies the need for additional work in relevant areas. Although this study was commissioned by DOE to help develop DOE funding priorities, the recommendations presented here go far beyond what DOE's budget can afford. We hope that utilities, their research institutes, and other organizations will use this report in setting their priorities for future work on least-cost planning. Based on the detailed assessments presented in this report, we suggest several foci for long-term LCUP efforts nationwide (Table S-1). Because current rate-of-return regulation rewards utilities for increasing short-term sales, perhaps the most important of these topics is the development of financial incentives for utilities (and their shareholders) to implement least-cost plans.

Real advances in planning are occurring, but others find it difficult to gain access to this knowledge and experience because these advances are rarely published. Therefore, expanded technology-transfer activities are needed to ensure that accomplishments in one

location are accessible to people in other utilities and commissions. Such activities include careful reviews and comparisons of utility plans and planning processes. In addition, assessments of planning success based on utility action plans (and their relationship to the utility's long-term resource plan) and interactions between the utility and regulatory commission are needed.

The amount of information available on demand-side resources (i.e., on the cost-effective programs that utilities can deploy to improve energy efficiency and cut peak demands) is much less than the amount available on supply resources. This difference exists largely because utilities have been building and operating power plants for a century but have been running demand-side programs for only a decade. Therefore, information on demand-side technologies and programs needs to be developed and disseminated widely.

Finally, increasing concerns about global warming and other environmental issues suggest that resource planning needs to explicitly include such factors.

The preceding discussion and Table S-1 dealt with the full breadth of LCUP activities without discussing which organizations might address particular issues. We suggest that DOE give the following topics high priority for the next year or two:

- Analyze alternatives to traditional rate-of-return regulation to reward utility shareholders for successful implementation of least-cost plans.

Table S-1. Long-term priorities for future work on least-cost utility planning

Assess regulatory alternatives that reward utilities for successfully implementing least-cost plans.

Expand training, networking, and other technical-support activities that share planning successes, analytical tools, and innovative regulatory strategies among public utility commissions and utilities.

Encourage and document successful institutional arrangements for resource planning and implementation.

Develop information on the performance and costs of demand-side technologies and programs to help balance the information available on demand and supply options.

Incorporate environmental and other social factors into resource planning.

- Analyze the processes used and the long-term resource plans prepared by utilities that currently use LCUP methods to suggest improved planning techniques that can be used in other locations.

- Continue and expand LCUP technology-transfer activities through conferences, training workshops, and technical assistance to utilities and regulatory commissions.

- Assess the pros and cons of utility auctions for demand-side resources, comparing separate auctions for supply and demand resources to integrated auctions. Develop alternative procedures that states and utilities can use to conduct competitive-bidding resource auctions.

- Compile information on successful conservation and load-management programs that can be used as models in other locations, emphasizing the commercial and industrial sectors because so little data exist on these sectors.

- Develop and assess methods to incorporate the environmental and social effects of different resource options.

LIST OF ACRONYMS

DOE	U.S. Department of Energy
DSM	Demand-Side Management
EPRI	Electric Power Research Institute
ERAM	Electric Revenue Adjustment Mechanism
LBL	Lawrence Berkeley Laboratory
LCUP	Least-Cost Utility Planning
NARUC	National Association of Regulatory Utility Commissioners
NORDAX	Northeast Region Demand-Side Management Data Exchange
ORNL	Oak Ridge National Laboratory
PUC	Public Utility Commission
ROR	Rate of Return
TBS	Temple, Barker and Sloane, Inc.

OVERVIEW

Electric utilities are undergoing fundamental changes. These changes include deregulation of electricity generation; greater access to transmission systems; competition for retail customers; changes in economic regulation; increased concern with the environmental consequences of electricity production and use; and considerable uncertainty about future load growth, fossil-fuel prices and availability, and the costs and construction times for different kinds of resources. Least-cost utility planning (LCUP) is a new and evolving process that can help utilities and state public utility commissions (PUCs) deal with these changes. LCUP consistently assesses various demand and supply resources to meet customer energy-service needs at the lowest economic and social cost. LCUP is important to utilities, their customers, and PUCs [Cavanagh 1986; Hirst 1988a; Hirst 1988b; National Association of Regulatory Utility Commissioners (NARUC) 1988] primarily because of problems that arose with traditional planning methods. These problems included a narrow focus on central-station power plants, limited consideration of uncertainties in planning, and little public involvement in planning.

Typically, the LCUP process begins with a situation analysis (top part of Fig. 1). The utility develops alternative forecasts of future electric loads, assesses the costs and remaining lifetimes of its existing resources, and identifies the need for additional energy and capacity resources consistent with corporate goals.

The second phase assesses alternatives that could satisfy the need for new resources (middle of Fig. 1). LCUP involves a much broader array of resources than the central-station power plants traditionally used by utilities. These supply, demand, transmission, distribution, and pricing alternatives are typically assessed with sophisticated computer models. Several integrated models have been developed during the past few years that encompass the functions of previously separate load-forecasting, capacity-expansion, production-costing, and financial-planning models. These analyses are repeated using (1) different assumptions about the external environment (e.g., local economic growth and fossil-fuel prices) and about the costs and performance of different resources and (2) different combinations of resources. These iterations help the utility to systematically consider all the reasonable resource options, the probabilities of occurrence associated with these options, and the risks and rewards associated with each option. This uncertainty analysis helps to identify a mix of resource options that meets the growing demand for electricity, is consistent with the utility's corporate goals, avoids exposure to undue risks, and satisfies other environmental and social criteria.

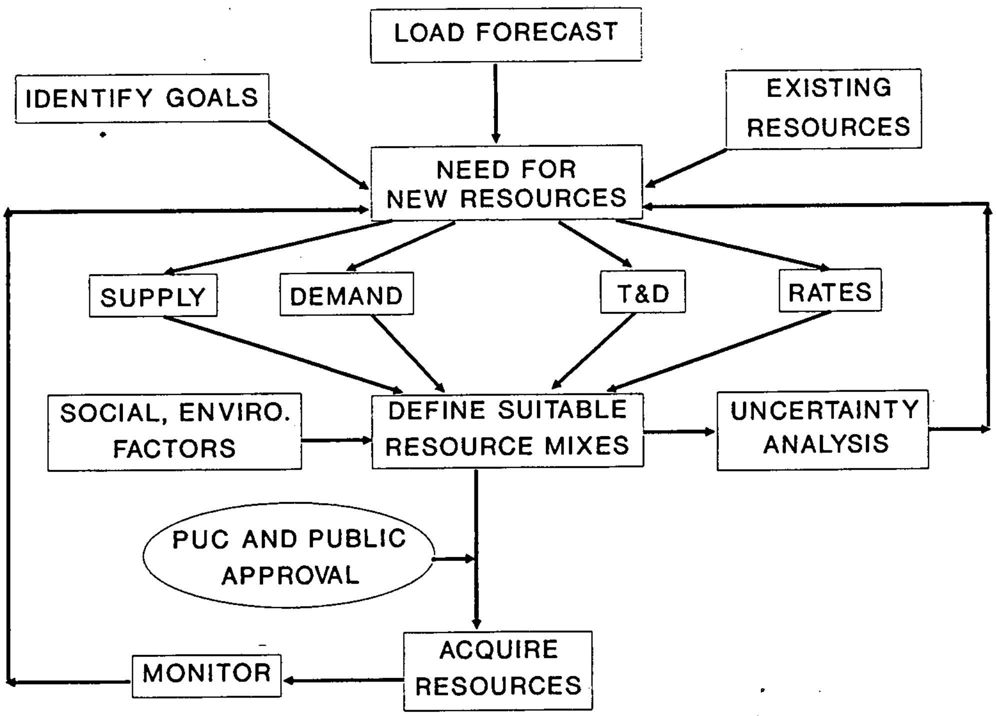

Fig. 1. Schematic showing the activities involved in least-cost utility planning.

After approval by the PUC (or other administrative or regulatory body, for public utilities), the plan is implemented (i.e., resources are acquired; bottom of Fig. 1). While the plan is in force, the utility monitors changes in its environment and its implementation of the resource plan, and the plan is modified as events and opportunities change over time.

Although the statutory authority for establishing LCUP rests with state legislatures and the responsibility for implementing LCUP rests with utilities and PUCs, the U.S. Department of Energy (DOE) is involved in these planning and regulatory changes because:

- LCUP programs could reduce the nation's energy bill by billions of dollars per year and could result in significant environmental, national-security, and economic-productivity benefits; reduce controversies over construction and siting of new energy facilities; and reduce capital costs for utilities.

- Major institutional and market barriers prevent the necessary decisions and investments that could bring about these national benefits.

This study was prepared for DOE's Office of Buildings and Community Systems, which is responsible for DOE's LCUP program. DOE asked Lawrence Berkeley Laboratory (LBL) and Oak Ridge National Laboratory (ORNL) to review LCUP progress during the past few years and to identify the need for additional work in this area. This report represents only one (albeit an important) input to DOE's planning for its LCUP program.

The findings and suggestions presented here are based primarily on the judgment and experience of LBL and ORNL researchers, supplemented by inputs from other experts in utility planning at electric utilities, PUCs, and other organizations. A draft of this report was reviewed by nearly 30 people from utilities, PUCs, congressional committees, DOE, and consulting firms. Although commissioned by DOE, the recommendations developed here go far beyond the scope of DOE's program. Our hope is that other organizations, especially the utilities and their research institutes, will use this report to help set their priorities for future work on least-cost planning.

The utility industry is huge, with revenues of more than $150 billion a year. By comparison, during the past four years DOE received only $1 to 2 million a year for its LCUP program. Strategic use of DOE's limited funds must be based on a clear understanding of the activities being pursued by the many other players in this field [e.g., the Electric Power Research Institute (EPRI), NARUC, and many utilities, state agencies, consulting firms, and public interest groups] and on an appraisal of needs not currently being met. One such appraisal was commissioned by DOE in 1986 in the form of a Temple, Barker and Sloane (TBS; 1986) survey of utilities, PUCs, research organizations, and public-interest groups. TBS reached the following conclusions:

- With few exceptions, PUC commissioners and staff do not have sufficient time, people, in-house expertise, analytical tools, or data to thoroughly analyze utility resource plans and the processes that produced them.

- Most utilities lack information on the cost, performance, and energy and load impacts of demand-side options; and on the market-penetration rates and energy and peak reductions that could be achieved with utility demand-side management (DSM) programs.

The TBS interviews and experience with LCUP since then suggest two principles that we believe guide the DOE program:

1. The DOE program considers its primary clients to be PUCs and their national association (NARUC). DOE focuses on state regulators for two reasons. First, PUCs establish the rules and procedures that govern the least-cost plans and planning processes used by electric and gas utilities. Second, the PUCs have few resources to conduct research, to perform analyses, or even to determine what is

happening in other locations (technology transfer). The utilities, on the other hand, have national organizations that are well funded for such activities, including EPRI, Edison Electric Institute, and American Public Power Association for electric utilities and Gas Research Institute and American Gas Association for gas utilities. Many utilities also have substantial budgets for inhouse staff and contractors to contribute to utility planning. Although DOE emphasizes projects with state regulators, it recognizes the importance of working closely and cooperatively with utilities because they are the organizations that prepare and implement resource plans (and because public utilities are generally not regulated by PUCs).

2. In addition, DOE's small budget requires it to focus on a few selected topics. These topics are chosen because they are important for utility planning, have national significance, transcend the perspectives of individual stakeholders (shareholders, ratepayers, utility employees, and interest groups), and are not adequately addressed by others. For example, DOE focuses on improving knowledge about DSM measures and programs, on developing collaborative processes within individual states, and on transferring useful methods and processes from one place to another. Issues such as deregulation, competition, transmission access, automation and control of distribution systems, cogeneration, and community impacts are not primary foci for DOE because these issues are being addressed by others.

In addition, DOE's work on LCUP issues can help the Department develop least-cost energy plans for the nation as a whole. Such plans are required in legislation proposed by Senator Wirth and by Representative Schneider (U.S. Congress 1989a and 1989b).

Since publication of the TBS report, substantial progress has been made. For example, state initiatives have spread to most regions of the U.S., and many utilities have prepared long-term resource plans in response to state legislation or regulation. Progress in overcoming the various obstacles to LCUP has been significant, and the perception of unresolved issues and further needs has considerably sharpened, partly because of DOE's program (Scheer and Millhone 1987; U.S. Department of Energy 1988). In some regions, such as the Pacific Northwest, Nevada, Wisconsin, and Maine, LCUP is a mature process within both commissions and utilities.

Meanwhile, utilities and PUCs in other regions are aggressively pursuing LCUP. This effort is motivated in some cases by anticipated capacity shortfalls, as in New England, and in other cases by rate shock, as in parts of Michigan, Ohio, Illinois, Massachusetts, and New York. A new initiative is also developing in the southeast, especially in North Carolina and Georgia.

Although substantial progress has been made during the past few years, much remains to be accomplished to achieve the benefits of improved long-term resource planning. Well-designed regulatory incentives for utilities to implement LCUP are still lacking, the quality of utility resource plans and regulatory review could be greatly improved, the data on alternative resource options (especially DSM options) are incomplete and insufficient, and the resource-selection criteria do not adequately reflect environmental and social factors.

Chapters 2 through 6 review recent progress in various aspects of LCUP and suggest future work in each area. In some instances, the distinction between tasks appropriate for DOE and for PUCs, utilities, and industry groups is made; in other cases, we identify important topics without suggesting who should lead these efforts. These recommendations are meant to guide further development of LCUP processes, techniques, and data so that the benefits LCUP can yield for energy consumers, public agencies, utilities, and the nation as a whole are realized.

THE PROCESS OF LEAST-COST PLANNING

Several broad topics that affect resource planning need to be considered, analyzed, and developed: (1) documentation (e.g., reports, articles, and computerized data bases) on how utilities and PUCs develop least-cost plans so that others can emulate and build on these successes; (2) methods to encourage collaboration among LCUP practitioners; (3) alternatives to traditional rate regulation that increase utility earnings when they implement cost-effective demand-side programs; and (4) the relationships between deregulation and competition on the one hand and long-term resource planning on the other hand.

LCUP is much more than the data and models used to analyze alternative resource portfolios. Perhaps the most important ingredients of successful LCUP processes are the three Cs: communication, cooperation, and consensus. DOE can play a catalytic role in implementing LCUP through the three Cs. It can stimulate and support institutional collaborations within and among states; document, analyze, and evaluate various approaches and experiences; and ensure that successful approaches are transferred to other states and utilities. Moreover, DOE can provide leadership by identifying the major national policy goals that are being inadequately addressed in state-based LCUP practice, by providing guidance on and coordination with national environmental and other policies, and by sponsoring analyses of important emerging LCUP issues.

TRACKING AND DOCUMENTING APPROACHES TO LEAST-COST PLANNING

Recent Progress

A few groups have surveyed states that have established some form of LCUP process (Arizona Corporation Commission 1987; Energy Conservation Coalition 1988; Electric Power Research Institute 1988). However, most of these efforts, including EPRI's forthcoming Demand-Side Information System, do not address the regulatory and institutional aspects of LCUP. NARUC has received funding for an electronic bulletin board and for gathering LCUP materials, but current funding is not nearly commensurate with this task.

In addition, detailed analyses of the different LCUP processes and their successes are lacking. NARUC (1988) recently completed a two-volume LCUP handbook for regulatory commissioners that discusses some of the principal approaches that are currently popular; an update of the handbook is planned for 1990.

Collaborative efforts involving diverse organizations are a potentially valuable way to gain consensus on controversial issues, such as the need for new power plants and the size and budget for a utility's conservation program. In the Pacific Northwest, the Northwest Power Planning Council (1986) and the Bonneville Power Administration have worked closely with each other, with the region's public and private utilities, and with other organizations on utility planning issues. More recently, the New England Electric System and the Conservation Law Foundation (1989) established a collaborative project on utility energy-efficiency programs, that is similar to arrangements that the Foundation has with other utilities in New England. Finally, ORNL is assessing several such ongoing regional collaborations that received funding from DOE (Berry and Hirst 1989).

Future Work

- Sponsor in-depth analyses of LCUP implementation in those regions where LCUP has been practiced the longest (e.g., Wisconsin, Maine, Nevada, and the Pacific Northwest) as well as process evaluations of implementation efforts in other regions. Assess LCUP success and problems by examining short-term action plans as well as long-term resource plans.

- Review the public involvement processes adopted by different utilities and commissions. Compare the types of groups involved and the costs and benefits of their participation in utility planning.

- Create an information and document data base consisting of key state LCUP legislation, rulemakings, rate cases, resource plan hearings, and similar activities. This data base should be linked to other LCUP documentation projects, data-base activities at the national laboratories, and commercial data bases covering regulatory developments.

STIMULATING COLLABORATIONS AND NETWORKING

Recent Progress

Networking among LCUP practitioners and analysts has greatly improved during the past few years. To date, EPRI has cosponsored four DSM conferences with DOE. NARUC held its first LCUP conference in April 1988 with funding from DOE; a second conference is scheduled for September 1989. The biennial Summer Study of the American Council for an Energy-Efficient Economy and The Energy Program Evaluation: Conservation and Resource Management conferences held in Chicago have also been important discussion forums for LCUP issues.

To stimulate LCUP, DOE also provided cost sharing for several collaborative efforts in Rhode Island (Xenergy 1988), Illinois (Collins 1988), Wisconsin (Prahl 1988), and Michigan (Krause et al. 1987).

Future Work

- Continue and expand support for networking, conferences, and other collaborative activities;

- Consider starting a Journal of Least-Cost Planning, with an editorial board representing EPRI, Gas Research Institute, NARUC, DOE, utilities, research organizations, and public interest groups.

DECOUPLING ELECTRICITY SALES AND EARNINGS

Utility acquisition of DSM resources is warranted: (1) when such resources are less expensive than supply alternatives, (2) when retail prices are lower than long-term marginal costs, (3) when they serve as a hedge against the risks associated with construction of large power plants, and (4) when they allow a utility to meet competition by offering valuable services to customers. In spite of these manifold benefits of DSM programs, many utilities show little commitment to the demand-side aspects of LCUP. This lack of interest is probably a consequence of the loss in profits caused by the revenue decline associated with electricity savings. Utilities are properly concerned with potential rate impacts that would reduce their competitiveness (spreading fixed costs over fewer kWh sales).

Recent Progress

These disincentives are the driving factors in the ongoing debate over which of several cost-benefit perspectives should be used to evaluate DSM programs. DOE helped clarify the test-related issues by funding Volume Two of the NARUC handbook, which reviews this debate (Krause and Eto 1988). It incorporates the "standard practice" test perspectives developed in California and estimates the rate impacts under each test perspective.

However, the standardization of tests does not address the profit component of the disincentives problem. In response to this failure, a number of proposals have been made to make DSM investments more profitable for utilities (Moskovitz 1988). They include the electric revenue adjustment mechanism (ERAM), rate of return (ROR) incentives for demand-side activities, bonus payments to utilities for achieving DSM targets, and shared-savings approaches (Table 1). NARUC (1989) plans to develop recommendations on the merits of such proposals by the end of 1989.

Table 1. **Description of alternative rate-making options**

Option	Definition
Conventional ROR[a] regulation - Without California-type ERAM[b]	Conventional ROR regulation establishes rates based on the formula: revenue requirements = expenses + rate base x rate of return. Consequently, the more investment a utility has in rate base the higher will be its rates and its profit, except in the unusual circumstance where the company's short run marginal costs exceed its rates. Furthermore, between rate cases the rates don't change. Thus, the more electricity or gas sold the higher will be a utility's profit.
- With ERAM	Same as conventional ROR regulation except that the utility's rates are later adjusted on the difference between predicted and actual sales to ensure that unexpected changes in sales volumes do not affect earnings.
Separate ROR for DSM investment	Rates are maintained as with conventional ROR regulation except that the rate base investment for conservation and load management is accounted for separately and, in a rate case, is calculated to earn a higher rate of return.
ROR adjustment for low bills	Same as conventional ROR regulation except that the rate of return in the revenue requirement formula is adjusted based on the ratio of the average annual utility bill for a set of comparable utility companies to the average annual total bill for the subject utility company.
Performance bonds	Same as conventional ROR regulation except that a third term is added to the revenue requirement formula used in a rate case. As an alternative, the ROR in the revenue requirement formula could be adjusted. In either case, the adjustment is based on the effectiveness of the utility in achieving LCUP goals.
Share DSM savings with utility	Same as conventional ROR regulation except that a third term is added to the revenue requirement used in a rate case. That added term is a predetermined percentage of the calculated savings that the utility can demonstrate from its DSM programs.
Bounty on DSM savings	Same as the previous option except that the adder to revenue requirements is not a percentage of the savings, but a predetermined amount dependent on the achievement of certain goals.

[a]ROR is rate of return.

[b]ERAM is electric rate adjustment mechanism, used in California to ensure that the utility recovers lost revenues associated with any overforecast of sales.

Source: National Association of Regulatory Utility Commissioners (1989).

Future Work

- Analyze alternatives to traditional ROR regulation to identify ways to reward utility shareholders for successful implementation of least-cost plans. Using utility-specific data and financial simulation models, compare alternatives. Focus on treatment of lost revenues caused by a utility's conservation programs and on ways to recover these revenues from different rate classes.

DEREGULATION AND COMPETITION

Recent Progress

The electric-utility industry may be undergoing fundamental restructuring. Forecast changes include mergers among utilities, deregulation of electricity production, greater access to transmission, and increased competition for retail customers. Although these issues are hotly debated, virtually no analysis has been done on the relationships between these possible structural changes and the need for, and benefits of, LCUP. Some argue that deregulation and increased competition obviate the need for integrated planning. Others claim that uncertainties about the future structure require even more planning; for example, some ask how a utility can conduct an auction for new resources without a least-cost plan that provides a benchmark against which new resources are compared.

Future Work

- Examine the relationships between acquisition of resources from private producers and least-cost planning. Should planning be a prerequisite to competitive bidding for new resources? Or will the need for utility planning be reduced by competition among new electricity providers? How can utility planning identify the extent to which workable competition exists among potential suppliers of new demand and supply resources?

- Review the effects of industrial bypass, increased competition from other fuel suppliers, and other forms of retail competition on utility least-cost plans (Cavanagh 1988). How does the increased uncertainty about future load growth implied by additional competition affect the utility's ability to plan and its traditional obligation to serve?

- Assess the effects on a utility's competitive position of short-term increases in prices stimulated by DSM programs. How large are these price increases, how long do they last, and how are they likely to affect industrial bypass, cogeneration, etc.?

- How might the incentives for a regulated distribution company to implement DSM programs differ from those facing the typical vertically integrated utility of today?

BROADENING THE SCOPE OF LEAST-COST PLANNING

As the environment in which electric utilities and PUCs operate has changed, so too have the issues related to resource acquisition. Emerging issues that affect long-term resource planning include bidding for DSM resources, treating electricity pricing as a "resource," extending LCUP principles to other fuels (especially natural gas), and incorporating environmental and social factors into LCUP.

BIDDING FOR DEMAND-SIDE RESOURCES

Recent Progress

Several PUCs and utilities have adopted competitive bidding systems to provide future electric capacity (Cole, Wolcott, and Weedall 1988; Michaels 1988; Nemtzow 1988). Utilities in Maine, Massachusetts, and Connecticut have conducted auctions that include DSM resources as well as power supplies. Bidding programs for DSM resources raise numerous resource-planning and program-implementation issues, such as the choice of combined or separate bidding for demand and supply resources, the treatment and values of nonprice factors in bidding, and measurement of the impact of DSM programs. A particularly contentious issue concerns the ceiling price utilities should offer for purchase of DSM resources: should it be the long-term avoided cost or just the difference between avoided cost and revenues? (This difference, related to the revenues lost to the utility because of improved energy efficiency, is substantial on both theoretical and practical grounds.)

Detailed case-study evaluations would be useful because most DSM bidding programs are only in their initial phases. LBL and ORNL are currently studying demand-side bidding. EPRI is also initiating a study of supply and demand bidding methods.

Future Work

- Conduct case studies of utility experience with alternative bidding systems (i.e., integrated auctions vs separate auctions for supply and demand resources).

- Identify circumstances under which DSM bidding is likely to be most successful as well as situations in which bidding is inappropriate.

ELECTRICITY PRICING AS A "RESOURCE"

Recent Progress

The crucial role of electricity pricing in affecting both the level and shape of electricity loads is increasingly recognized within utilities and PUCs as a "resource" that can complement traditional supply-side and demand-side alternatives. Since passage of the 1978 Public Utility Regulatory Policies Act, debates about marginal-cost pricing have occurred in virtually every state. Participants generally agree that pricing electricity close to its marginal cost is desirable in terms of economic efficiency. Differences occur, however, on how to define marginal costs, on whether to use short-term or long-term marginal costs, and on how to apply such pricing schemes to customers that do not use much electricity. Using pricing as a marketing tool to encourage customers to participate in a utility's DSM programs is also of substantial interest.

A growing number of utilities offer optional or mandatory time-of-use rates, especially to their larger customers. Also, the number and variety of interruptible and standby-generator rates designed to cut demand during peak-load and emergency situations are increasing.

Future Work

- Building on EPRI's decade-long Rate Design Study, review the literature on the theory, practice, and practicality of different forms of marginal-cost pricing.

- Assess recent advances in microcomputers, telecommunications, and other technologies that affect meter reading, billing, and the costs of time-of-use metering, demand metering for residential customers, and smart meters for real-time pricing.

- Examine the possible roles of alternative electricity-pricing schemes to improve energy efficiency and/or load factors, considering various forms of interruptible rates, time-of-use rates, and incentive rates for participation in DSM programs. Assess the benefits and costs of current utility experience with such rates.

EXTENDING LCUP TO OTHER FUELS

Recent Progress

The current exclusion of fuel switching (e.g., from use of electricity to gas for residential space heating) from most LCUP analyses has resulted in incomplete conclusions regarding optimal capital allocation in the energy system. For example, some electric utilities propose that expensive water-heater controls be used when switching to gas water heaters would be cheaper for consumers. Conversely, in some industrial processes, switching from gas to electricity may be indicated despite less expensive gas services, because electricity may bring process-specific productivity increases. Fuel switching in either direction could provide significant emission benefits, depending on the source of electricity.

Extending LCUP beyond the electricity sector would not only increase competition between electric utilities and other energy suppliers but also entail complex institutional and policy questions. There are significant differences between the gas- and electric-utility industries with respect to structure, regulatory practices, markets, and current and projected supply/demand balances. For example, the gas industry is not dominated by vertically-integrated firms that control and are responsible for all aspects of production and transportation to final users. Moreover, the natural gas industry is partially deregulated, and the oil and coal markets are unregulated. Increased concerns about the environment could increase interest in fuel switching as an important resource option. To date these issues have been insufficiently studied. Conducting such interfuel comparisons is complicated by uncertainties about future fuel prices, greater volatility in gas and oil prices than in electricity prices, and customer preferences for different fuel/equipment combinations.

Future Work

- Conduct detailed case studies at various geographic levels (utility service area, regional, and national) to estimate potential energy savings and economic benefits from fuel switching between electricity and fossil fuels along the lines used by the Northwest Power Planning Council (1988). Focus on applications where established commercial technologies operated by either electricity or fossil fuels offer large benefits but where market barriers prevent equilibration. Such a cost/benefit analysis should include long-term supply security and environmental implications, efficiency improvements in the use of all fuels, and productivity increases.

- Initiate pilot-scale utility programs on fuel switching. Possible test applications include high-efficiency electric versus gas water heaters in the residential sector and thermal (cool) storage systems versus absorption chillers in commercial buildings. Such projects are especially relevant to combination (gas and electric) utilities.

- Review alternative approaches to application of least-cost planning to gas utilities, building on the recent experiences in the states of Washington and New York and in Washington, DC. Such a review would underscore the structural differences between gas and electric utilities.

INCORPORATING ENVIRONMENTAL AND SOCIAL FACTORS

Failure to consider external factors is an important shortcoming of current LCUP practices. This failure often leads to outcomes that are socially suboptimal because many resource options entail significant social costs that are difficult to quantify. The need to reduce environmental impacts may require an approach that includes environmental as well as other costs (Table 2). Such a broadened approach to utility planning should also encompass possible regional economic benefits associated with electricity use and the income-distribution effects of different resource strategies.

Recent Progress

The U.S. Congress (1980) recognized the importance of environmental factors by giving conservation resources a 10% bonus in economic calculations in the Pacific Northwest; thus energy-efficiency resources costing up to 10% more than the best supply alternatives are acquired. The Wisconsin Public Service Commission recently adopted a similar approach that gives conservation a 15% credit.

In designing acid-rain-abatement policies, reducing emissions at least cost is important to minimize burdens on ratepayers and regional economies (Centolella 1988; Geller et al. 1987). This objective requires comparison of the cost of scrubbers and other pollution control with the cost of alternative resources. The range of alternative resources should include gas-fired high-efficiency combined-cycle or steam-injection plants, clean-coal plants, gas-cooled nuclear plants, cogeneration plants, renewable resources, fuel switching, and end-use-efficiency improvements.

Ultimately, the specter of global warming may lead to dramatic changes in LCUP practices. For example, future utility planners may be required to develop resource plans that achieve specific carbon dioxide reduction targets. At a recent conference in Toronto, experts called for a 20% reduction in global carbon dioxide emissions by the year 2005. In response, NARUC passed a resolution calling upon the federal government to initiate carbon-dioxide-reduction measures.

With the exception of acid rain, little research has been done on the relationship between resource acquisition and environmental issues. In some cases, least-cost plans do not adequately account for even those costs that could be quantified and incorporated on the basis of presently available data. For example, in a recent least-cost plan, the costs for life extension of existing plants excluded retrofits to meet emission standards required of a new plant.

Table 2. Environmental, health, safety, and other problems related to energy systems[a]

Global consequences of energy use	
	Greenhouse effect
	Stratospheric ozone depletion
	Nuclear accidents and proliferation of nuclear wastes
Multinational consequences	
	Acid rain
National consequences	
	Environmental, health, and safety aspects of fuel cycles
	Long-term storage of nuclear wastes
Local and regional consequences	
	Smog and carbon monoxide
	Land and water resources
	"Not in my back yard" syndrome (aversion to construction of power plants, transmission lines, or substations near one's location)

[a]Based on Fulkerson et al. (1988).

Initial studies on acid rain have been conducted for the Midwest, for Ohio, and for two coal-intensive utilities (Tennessee Valley Authority and American Electric Power) on the potential role of conservation as a component of least-cost emission reduction. DOE's LCUP program sponsored analyses of: (1) methods to include social costs in the valuation of power produced by cogenerators and renewable sources by the Ohio Public Service Commission and (2) methods to value the benefits of renewable electricity sources (Renewable Energy Institute 1988).

Future Work

- Review current LCUP regulation for incorporation of environmental externalities.
- Review and assess alternative approaches to coordination among the state agencies charged with utility regulation and environmental protection.
- Compile available information on the costs of producing and delivering different fuels to end users (on a $/Btu basis), considering the environmental effects of these activities on humans, plants, animals, air, soil, water, and manmade facilities.

- Assess how carbon dioxide emissions in the U.S. electricity sector could be reduced at least cost; examine this least-cost plan for undesirable increases in other externalities.

- Complement this national analysis with regional or service-territory case studies on the potentials and financial and economic impacts of carbon-reduction targets; develop specific guidelines for utilities and PUCs on relationships between national climate-stabilization targets and cost-minimizing carbon-reduction strategies for particular regions.

- Analyze acid-rain-abatement policies, including (1) the financial incentives and disincentives for least-cost abatement under current regulatory requirements, (2) incorporation of DSM programs into abatement planning, and (3) comparison of least-emissions dispatch and lowest-operating-cost dispatch using detailed models and plant-specific emissions.

ADVANCING THE TECHNIQUES OF LEAST-COST PLANNING

Significant efforts are needed to improve the technical and analytic soundness of current least-cost planning. The main difference between a conventional plan and a least-cost plan is that the latter integrates a broader set of resource options, notably DSM resources and independent power production (Fig. 1). The availability, reliability, load-shape impacts, unit size, lead times, costs, and other characteristics of these resource options are different from those of conventional central-station technologies. To effectively integrate all options, it is necessary to perform new and more complex screening and analysis (Eto 1987; Kahn 1988).

Both utilities and PUCs find it difficult to adjust to these new demands. Commission staff often lack the necessary technical training to evaluate utility filings and assure quality control. Commissions may provide inadequate guidelines for the preparation and documentation of the least-cost plan. And planners are often overwhelmed with massive filings, conflicting formats, and inconsistent levels of detail (Hirst 1988b).

A variety of technical problems complicate LCUP. One important methodological issue is the proper choice and use of computer models for preliminary screening of individual resources, for development of resource portfolios, and for detailed analysis of a few attractive resource portfolios. The treatment of uncertainty is of special importance, because it is a dominant problem in power planning. Integration of DSM resources into the overall resource plan is also quite difficult.

Recent Progress

In some jurisdictions (e.g., California, Wisconsin, Northwest Power Planning Council, and Maine), commissions and utilities have developed standardized procedures for filings and plan preparation that codify aspects of sound LCUP planning techniques. In California, the legislature stipulated quality-control procedures for utility-planning models. Questions remain, however, about the rigidity imposed by too much standardization and, more generally, about how to prepare and review least-cost plans. DOE projects at LBL and ORNL assess LCUP techniques among different states and utilities. LBL is helping the New York Public Service Commission review utility DSM and integrated-resource plans (Goldman and Kahn 1989). And ORNL is reviewing the long-term resource plans and short-term action plans of several electric utilities (Hirst and Schweitzer 1988).

EPRI developed several DSM screening models and production cost models, as well as integrated planning models that incorporate the major elements of the utility planning process (Fig. 2). The Bonneville Power Administration developed an integrated Conservation Policy Analysis Model to assess alternative DSM strategies for the Pacific Northwest electric system (Ford and Geinzer 1986). DOE funded a model-development project for the planning needs of American Public Power Association members. DOE also supports work at ORNL on ways to improve the treatment of uncertainty (Hirst and Schweitzer 1988).

Future Work

- Review and document the technical plan preparation and filing guidelines currently used in established state LCUP processes and evaluate the degree to which they address pertinent planning methodology, modeling, and data requirement issues.

- Conduct case studies to determine the experience with each major quality-assurance approach in each area of plan preparation and transfer this experience to other states.

- Review utility planning models for technical capabilities, relevance to different aspects of the planning process, ease of use, data requirements, cost, and other factors.

- Conduct training workshops for PUC and utility staff. Focus on specific technical components of LCUP methodologies, such as use of strategic planning models, end-use forecasting, and DSM resource assessment.

- Building on the California standard practice manual and the EPRI (1987) *Technical Assessment Guide*, develop an expanded standard practice methodology for least-cost planning and guidelines for plan evaluation.

- Develop expanded load-forecasting models that explicitly incorporate the effects of utility DSM programs. Without explicit inclusion of explanatory variables related to these programs, whether the forecasts include the effects of past and current programs is unknown.

- Compare the risks and uncertainties, both perceived and real, of different demand and supply resources. Assess the benefits of lead time, unit size, and flexibility for different resources. Compare the level of effort devoted to collection, analysis, and publication of data on supply vs demand resources and suggest approaches to redress any observed imbalance.

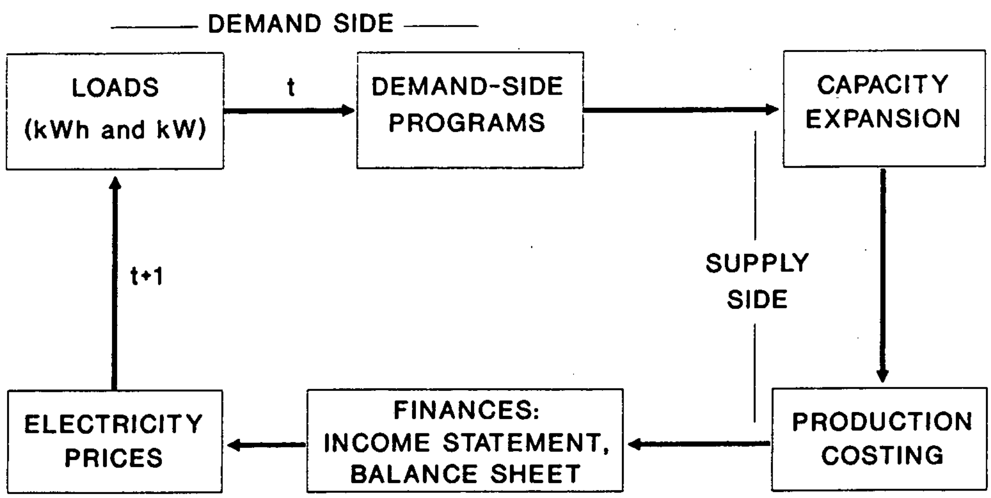

Fig. 2. **Schematic of a typical integrated resource planning approach, showing the different submodels; t refers to the year of analysis.**

DEMAND-SIDE INPUTS TO LEAST-COST PLANNING

The quality of data currently used in least-cost planning needs to be significantly improved, especially on the demand side (Caldwell 1987). PUCs share responsibility with utilities to ensure that DSM programs are carefully planned and evaluated, so that reliable data on the unit cost and size of resource options are available. Supply resources tend to have large uncertainties connected with future fuel prices, siting problems, construction times, and capital costs. Large uncertainties are also associated with DSM resources, especially with respect to participation rates.

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 available DSM data, and lack of agreed-upon guidelines to ensure quality control. Because a great imbalance exists between current knowledge on the supply-side compared to the demand-side, we focus our assessment on the latter. To quantify the cost and size of DSM resources, the following ingredients must be combined:

- Baseline data on the efficiency and utilization patterns of end-use technologies in the existing stock,
- A comprehensive technology data base on costs and performance of energy-efficiency and load-management technologies,
- Data on persistence of actual energy and load reductions, administrative costs, customer acceptance by market segment, and participation rates for different types of utility DSM programs.

These different elements are discussed in the following three sections.

END-USE LOAD SHAPES AND OTHER BASELINE DATA

Recent Progress

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 (Turiel and Lebot 1988; Usibelli 1983). Adequate baseline data (e.g., hourly loads by end use) are important for assessments of DSM technology performance, market-penetration rates, and utility-system-load impacts. Utility needs for end-use data have steadily increased, as have efforts and money invested in monitoring of end-use loads. However, end-use monitoring is costly and time-consuming, and the volume of data makes data reduction and analysis cumbersome.

Future Work

- Identify ways to transfer load-research results from one location to another.
- Cosponsor ongoing efforts to compile, analyze, compare, and publish measured end-use load data from many sources.
- Develop and disseminate 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).
- Cosponsor efforts to fill the most important gaps in end-use load profile data (e.g., cooling and "miscellaneous" end uses).

TECHNICAL AND ECONOMIC ASSESSMENT OF DEMAND-SIDE TECHNOLOGIES

Regulators want utilities to consider a comprehensive list of efficiency and load-management technologies, and both regulators and utilities need credible, up-to-date cost and performance data. Because of the many technologies and applications involved and because of the speed of technical innovation, technology assessments need to be updated regularly. Credibility of technical information is enhanced if based on measured field data.

Recent Progress

Many assessments of end-use efficiency and load-management technologies have been undertaken by EPRI, the national laboratories, and other organizations, such as the Rocky Mountain Institute (Lovins and Sardinsky 1988). One convenient way of representing the aggregate potential of DSM resources is through a supply curve of conserved energy or peak power (Meier et al. 1984). 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). Most case studies of DSM resources concentrated on the residential sector; thus, the commercial and industrial sectors are poorly understood. In addition, coverage of individual end uses and technologies is uneven and incomplete, although DOE has funded several technology assessments as part of the LCUP program (Piette, Krause, and Verderber 1989).

Future Work

- Establish a comprehensive list of technologies that can be included in utility DSM plans; regularly update the list. Each entry should be evaluated in terms of currently available technology assessments, field performance data, comparisons of actual vs predicted savings, and further assessment needs.

- Support on-going activities to perform clearinghouse and updating functions on technology cost and performance.

- Analyze demand-side resources and baseline data for the commercial and industrial sectors.

- Continue development of modeling software to simplify DSM resource analysis. Most studies have relied on custom-made software and analytical procedures, which can consume inordinate amounts of time. Common software will also facilitate comparisons among studies.

PROGRAM EXPERIENCE AND MARKET PENETRATION

Utilities and regulators may have different ideas about how aggressively DSM resources should be implemented. In reviewing DSM plans, it is therefore important to be able to compare penetration rates of proposed programs with the range of participation rates that could be achieved based on available program design and customer acceptance experience (Fig. 4). In addition, program designs can greatly influence the total cost of demand-side measures borne by the ratepayers as opposed to the participants. Efficient program design can minimize adverse rate impacts.

Many programs sponsor several different DSM measures at the same time. Programs influence specific networks of manufacturers, wholesalers, retailers, installers, designers, and other trade allies that differ by technology. And consumer-purchase decisions are based on many attributes other than energy efficiency. Therefore, it is necessary to analyze program experiences with individual technologies and market segments. Systematic experimentation with alternative program designs and monitoring and documentation of program impacts are two areas that need additional emphasis.

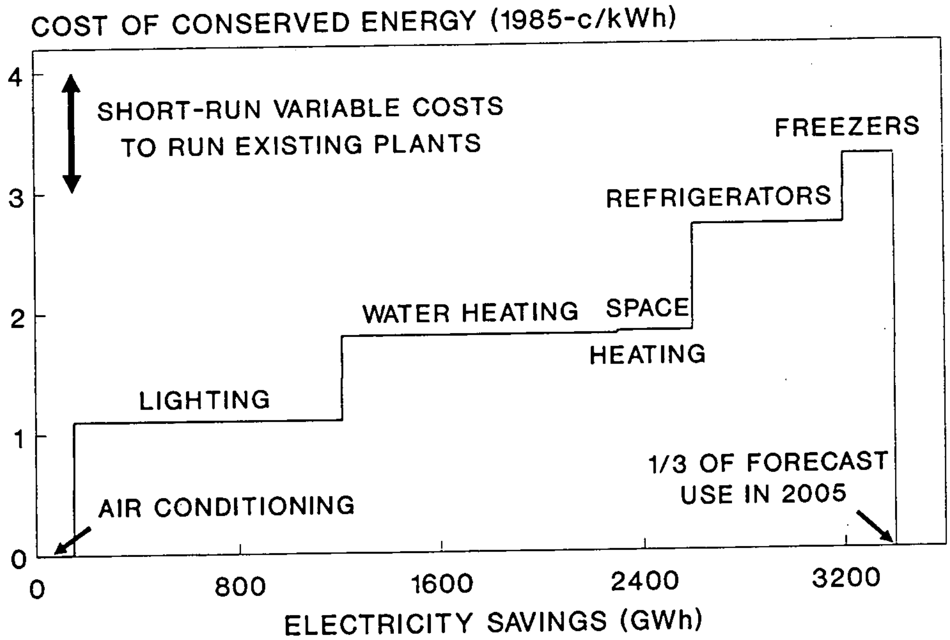

Fig. 3. **Residential conservation supply curve for Michigan (Krause et al. 1987). The cost-of-conserved-energy estimates are based on a 3% real discount rate.**

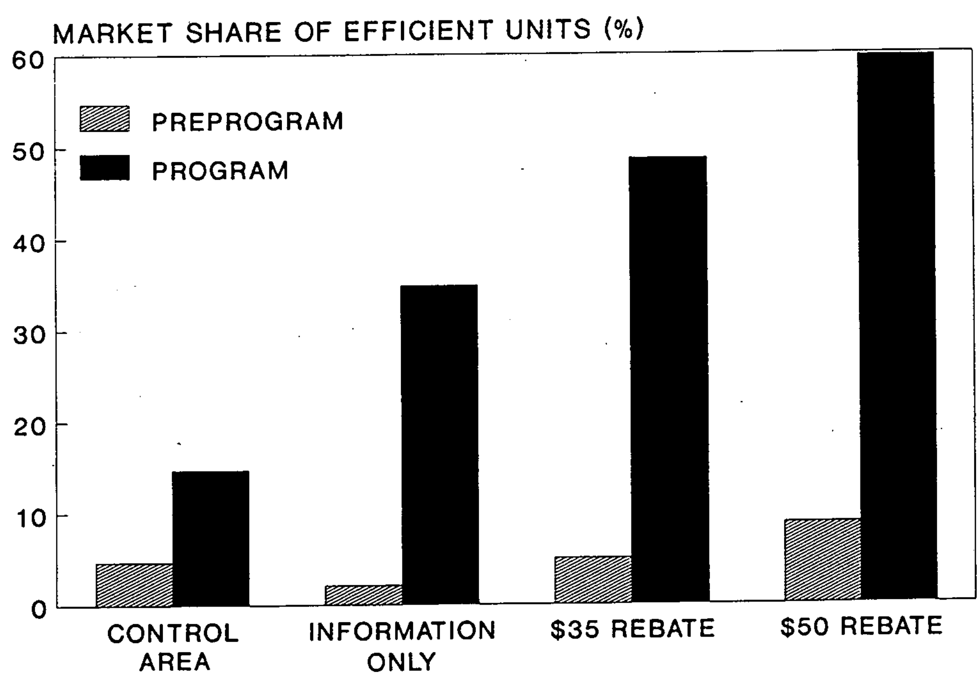

Fig. 4. **Market shares of high-efficiency refrigerators before and during a pilot program run by New York State Electric and Gas Corporation (Kreitler and Davis 1987).**

Recent Progress

A few types of programs for particular market segments have been reviewed. Berman, Cooper, and Geller (1987) surveyed utility rebate programs. EPRI assessed lessons learned in residential and commercial sector programs (Davis et al. 1988). Results from many in-house evaluations of utility and government programs are reported at the major DSM conferences. The Bonneville Power Administration conducts what is probably the most comprehensive and successful DSM evaluations of all (Keating and Riewer 1987). DOE co-funded a regional program experience data base (Northeast Region Demand-Side Management Data Exchange, NORDAX), sponsored by about 20 utilities in the Northeast. DOE also funded several evaluations of utility programs by ORNL, LBL, and Argonne National Laboratory.

Future Work

- Analyze the quality of information obtained through the NORDAX data base. Study several specific programs using NORDAX and other information sources.

- Establish program-experience collection efforts for other regions of the U.S., building on the NORDAX experience.

- Periodically survey utility program activities. Correlate pilot and full-scale program activities with a list of available DSM technologies, monitor program coverage of technologies, and track the kinds of evaluations available for each program.

- Analyze a variety of programs to improve coverage by end use and sector. Focus on equipment rebate programs, industrial programs, and the use of pilot programs to predict impacts of full-scale programs.

- Document successful DSM programs and the reasons for their success.

- Investigate and compile data on participation in key DSM programs to estimate the fraction of participants that would have adopted the recommended energy-efficient actions without the utility program and to ensure consistency between load forecasting and DSM planning.

- Develop guidelines and procedures for program monitoring, process and outcomes evaluations, pilot project experimentation, and other aspects of improved program design and analysis.

TECHNOLOGY TRANSFER

Technology transfer in utility planning has two aspects. One is the quality, completeness, and accessibility of the written information and data needed for least-cost planning (EPRI 1985). The second is effective person-to-person interaction in transferring experience among individuals and organizations.

Both of these aspects are governed by the degree, and under what circumstances, it is appropriate to transfer technical data and program ideas from one utility or region to another. This question has no single answer. Some program strategies and technical data are broadly applicable; others are unique to local market conditions or institutional characteristics. A more relevant question is whether prospective users of transferred results have access to all the information (on failures as well as successes) they need to decide whether a lesson learned elsewhere is of value to them.

Recent Progress

As DSM programs mature, the need for convenient access to high-quality, comprehensive, and timely technical and program data will increase. Some important first steps in this direction include EPRI's Demand-Side Information System, NORDAX, and NARUC's exploratory effort to develop an on-line listing of DSM materials for regulators. In addition to these special-purpose reference systems, a number of energy and technical reference sources (including DOE's Energy Data Base) are already available online through commercial information services such as DIALOG.

These DSM-related reference systems could be more closely integrated through a cross-referencing capability that allowed an online user to easily access more than one system without redefining keywords or other search procedures and without wasting time and money on duplicate entries.

In addition to improvements in published information, increased networking among professionals and their institutions is important. The Energy Services Exchange, run by the American Public Power Association, is a successful model that could be replicated elsewhere. The Northwest Power Planning Council manages a networking activity in that region involving the evaluation staffs of utilities, state agencies, and the Bonneville Power Administration in regular meetings on work completed or in progress. Similarly, one of the most important achievements of NORDAX may be the informal meetings among utility staff members to discuss a wide range of DSM topics. This type of peer-to-peer contact is not only an efficient means of transferring information but also a reinforcement of the importance and "professional" dimension of DSM activities.

Future Work

- Prepare and regularly update a list of reference sources that summarizes the major features, contents, and organization of the various online or hard-copy sources of LCUP-related bibliographic and project information.
- Identify (and, where possible, resolve) major gaps or inconsistencies in coverage of LCUP topics by the existing reference sources.
- Provide the reference services with abstracts on the most important items from the unpublished (grey) literature (e.g., reports prepared by utilities or consulting firms).
- Sponsor networking demonstration projects on a regional basis (as with NORDAX) or among other groups that would benefit from closer interactions (e.g., small investor-owned utilities or PUC staffs).

CONCLUSIONS

Least-cost utility planning considers a much broader array of energy resources than traditionally planning approaches do, including end-use-efficiency investments and load management by utilities, transmission and distribution options, alternative pricing options, and dispersed power generation. Such broadened planning can yield enormous benefits to consumers and society. LCUP benefits include acquisition of resources that meet customer energy-service needs in ways that are low in cost, environmentally benign, and publicly acceptable. LCUP 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. A significantly expanded national LCUP program that includes utilities, commissions, DOE, and other organizations is warranted.

Based on the detailed assessments in the Appendix of this report, we suggest several areas as the primary long-term foci for LCUP efforts nationwide (Table 3).

Table 3. Long-term priorities for future work on least-cost utility planning

Assess regulatory alternatives that reward utilities for successful implementation of least-cost plans.
Expand training, networking, and other technology-transfer activities that share LCUP successes, analytical tools, and innovative regulatory strategies among PUCs and utilities.
Encourage and document successful institutional arrangements for resource planning and implementation.
Develop information on the performance and costs of demand-side technologies and programs to help balance the information available on DSM and supply options.
Incorporate environmental and other social factors into resource planning.

Within the constraints of current funding levels, DOE is playing a limited, targeted role to help PUCs and utilities achieve potential LCUP benefits. DOE's LCUP program funds projects with PUCs, public and private utilities, state energy offices, research and trade associations, and experts at national laboratories and consulting firms.

DOE's diverse program has funded projects related to data bases, model development, legal issues, methods for incorporating renewable resources and cogeneration into utility plans, creation of new organizational structures and consensus-building processes, analysis of demand-side bidding mechanisms, risk and uncertainty analyses, technology assessments, market-penetration studies, development of conservation supply curves, and technology transfer.

Consistent with the limited funding for DOE's LCUP program, we suggest that DOE give the following topics high priority during the next few years:

- Analyze alternatives to traditional rate-of-return regulation to reward utility shareholders for successful implementation of least-cost plans.

- Review the LCUP processes and the long-term resource plans prepared by utilities in several states. Use this information, on both process and plans, to suggest improved planning methods that can be used in other locations.

- Expand the technology transfer activities of LCUP conferences, training workshops, and technical assistance to utilities and commissions.

- Assess the pros and cons of utility auctions for DSM resources, comparing separate auctions for supply and demand resources to integrated auctions. Develop alternative procedures that states and utilities can use to conduct competitive-bidding resource auctions.

- Compile information on successful DSM programs that can be used as models in other locations, emphasizing the commercial and industrial sectors because so little data exist on these sectors.

- Develop and assess methods to incorporate the environmental and social effects of different resource options.

Successful development and implementation of least-cost plans can save billions of dollars a year for U.S. energy consumers, reduce the need to build large, expensive generation and transmission facilities, improve the financial performance of utilities, reduce emissions of greenhouse gases and other pollutants, enhance national security, improve economic productivity, and smooth relations between utilities and their commissions and customers. None of these benefits will occur overnight, nor will they be easy to achieve.

But they are well worth working for, which is why DOE, utilities, PUCs, and other organizations should expand their efforts on long-term energy-resource planning.

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