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IRP Methods for Environmental Impact Statements of Utility Expansion Plans

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Abstract

Most large electric utilities and a growing number of gas utilities in the United States are using a planning method - Integrated Resource Planning (IRP) - which incorporates demand-side management (DSM) programs whenever the marginal cost of the DSM programs are lower than the marginal cost of supply-side expansion options. Argonne National Laboratory has applied the IRP method in its socio-economic analysis of an Environmental Impact Statement (EIS) of power marketing for a system of electric utilities in the mountain and western regions of the United States. Applying the IRP methods provides valuable information to the participants in an EIS process involving capacity expansion of an electric or gas utility. The major challenges of applying the IRP method within an EIS are the time consuming and costly task of developing a least cost expansion path for each alternative, the detailed quantification of environmental damages associated with capacity expansion, and the explicit inclusion of societal impacts to the region.

Introduction and Background

In recent years, public utilities across the United States have extended their abilities to provide reliable and low cost service to energy end-users by developing Demand-Side Management (DSM) programs. The greatest use of DSM programs in recent years has been in electric utilities, though gas utilities also have begun to implement DSM plans and programs. Approximately 500 electric utilities in the U.S. currently are sponsoring over 1,300 DSM programs [1] and a majority of states require electric utilities to formulate periodic Integrated Resource Plans (IRP) which incorporate energy conservation and peak load management options in utility expansion plans whenever the marginal costs of such options are lower than the marginal costs of supply-side alternatives [2].

DSM programs are activities undertaken by utilities to alter the usage patterns of their customers. Two examples of such programs are direct control of residential air conditioners by the electric utility on days of peak load and utility incentives to install energy efficient lighting. The benefits of DSM programs such as these are potentially significant, but to generate the benefits strategic and system-wide planning is required. The direct control of residential air conditioners, for instance, can offset the need for the construction of expensive peaking plants without significantly reducing utility revenues. Reducing air conditioning load can be important since residential air conditioners consume as much as 45 percent of the residential summer peak load in American metropolitan areas. Subsidies to investments in energy efficient lighting systems - if the investment would not otherwise occur - can reduce SO_2 pollution as fewer coal-fired plants need to be operated. Electricity demand for lighting have been estimated to be

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approximately 20 percent of total annual electricity demand.

IRP can provide a mechanism for capturing the potential benefits of DSM programs while meeting the load and reliability requirements Americans have come to expect and demand from utilities. The key characteristic of the IRP method is the explicit consideration of peak load management and energy conservation programs as alternatives to power generating facilities. IRP differs from older methods of utility planning in several fundamental ways. First, IRP recognizes that electricity and natural gas are not consumed for their own sake, but for the heating, cooling, lighting, or other services the energy produces when used with some capital or durable good. The IRP method looks beyond the meter to bring the knowledge of experienced, cost-conscious utility engineers and economists to the union of equipment and energy in the service of the consumers' needs. Second, the IRP method makes the widely-held assumption that energy consumers face market barriers which prevent them or unduly discourage them from making investments which would permit more efficient use of electricity or gas. Under this assumption, it becomes imperative that the utility actively pursue a larger role than just supplier of energy; the utility must encourage and assist consumers to use energy resources wisely and to the maximum social benefit. For instance, providing and installing electric water heater blankets to older or income-constrained customers can reduce wasteful use of electricity, save fossil fuel resources, and reduce pollution from baseload power plants. Finally, the IRP method seeks to balance DSM programs with the conventional supply-side options of capacity expansion. Such a balance is not found by simply choosing DSM programs, reducing the load forecast by the energy savings of the programs, and subsequently planning to meet the net load growth with capacity expansion only. A balanced plan permits demand and supply options to compete for a place in the utility's portfolio of DSM programs and plant capacity. Others [3] have argued for the inclusion of DSM programs in utility plans for different reasons, but the "level playing field" equal treatment of DSM and supply-side options is essential for the application of scientific and unbiased methods in utility planning. These features which distinguish IRP from traditional utility planning aim at finding the least costly method of satisfying customer needs for energy services.

Argonne National Laboratory has applied the IRP method in an innovative project for the Western Area Power Administration (Western). An Environmental Impact Statement (EIS) is being written to address the effects of changes in the electric power marketing criteria used by Western for a five state area around 7 hydroelectric power plants. Western markets electric power generated by the U.S. Bureau of Reclamation, selling it to meet part of the loads of many rural cooperative and municipal utilities. If Western changes its power marketing criteria - e.g., by requiring an increase in the Minimum Scheduled Requirements to its customers with no change in their Firm Power allocations, thus selling its energy less like a peaking or cycling plant and more like a baseload plant - then Western's customers will need to adjust their capacity expansion plans and may find a place in their plans for DSM. Argonne's use of the IRP method focuses on Western's customers and will allow Western to anticipate their customers' planning responses. Of major importance to Western is the extent to which their customers will use DSM programs to service the needs of end-users.

Types of DSM

DSM programs can be classified into four categories: peak shaving, load shifting, valley filling, and energy conserving [cf. 4]. Each class of programs can fill a specific need in a utility's plans and no single DSM program is likely to entirely replace a major power plant, but DSM plans woven carefully together can conserve enormous amounts of energy and capacity. Estimates of the energy saving, in fact, have ranged from 24 to 75 percent of electricity demand [5]. A brief description of the four categories of DSM programs is given below with examples of individual programs which can fit into the categories.

Peak shaving DSM programs are often most attractive to utilities. By reducing the peak utilities can eliminate what is often the most costly portion of its annual load. Utilities need to build their systems to meet their peak load, and yet a utility's pricing structure almost inevitably connects revenues most directly to its monthly and annual energy sales. Peak load management programs reduce the utility's capacity requirements without substantially reducing monthly energy sales since only a few hours of load are affected. Examples of peak load shaving programs are special lower demand and energy rates for industrial interruptible service and billing credits for commitments by commercial and industrial customers to reduce load by specified amounts at the utility's request Since many commercial and industrial customers have fixed working hours or routine energy usage patterns, there is no sizeable bounce-back or "payback effect" after the control period. A "payback effect" is where the customer load partially compensates for the control period by growing immediately after the period of control. Such commercial and industrial peak load management programs usually are organized directly by the utility. Some innovative organizations, however, have appeared through which the load management program is developed outside of the utility as a cooperative venture. One interesting example of this cooperative structure is the Commonwealth Edison Energy Cooperative in Chicago, of which Argonne National Laboratory is a member and participant.

Load shifting is a second general type of DSM program. This class of programs include: Time-of-Use pricing, discounts on the purchase of appliance timers, incentives for the installation of cool storage systems, and direct load control of residential air conditioners and water heaters. Programs of this type shift load from hours of peak demand (usually in the early and middle afternoon) to hours of low demand. Most of these programs reduce both peak load and overall energy sales, but some do not. Direct load control of residential air conditioners, for instance, reduce peak load, since the program is operated only during peak periods on hot summer days, and lowers energy sales since the "payback effect" after the control period only partially recovers the lost load during the control period. In contrast, the installation of cool storage systems will increase overall energy sales while reducing peak demand as the storage of cooling capacity in water or ice is not 100 percent efficient.

Valley filling is a DSM approach which stimulates the utility's demand during off-peak hours and non-peak seasons (usually in the very early morning hours and the spring and autumn seasons). Though valley filling initially may seem wasteful of energy resources, there are situations in which valley filling can lead to increased efficiency. One example of valley filling is the payment of incentives for the purchase of electric heat pumps or gas absorption air conditioners in regions with electric utilities that have strong summer peak loads. A second example is the encouragement of electric vehicles as replacements for gasoline-engine cars. Valley filling can lead to increased efficiencies if it raises the load factors of electric and gas utilities and enables the utilities to use more economical generating or supply technologies. That is, if an electric utility could change its capacity mix to reduce the usage of high-cost peaking and cycling plants and increase the usage of efficient baseload plants, overall system efficiency could be improved [cf. 6]. Naturally, utilities executives are as fond of valley filling DSM programs as conservationists are wary of them. One is reminded that what must have been the first DSM program was that of Thomas Edison in the 1890's. Edison hired people to promote the use of electric motors and other daytime uses of electricity to counterbalance the nighttime lighting load [2].

Energy conserving DSM programs are activities undertaken by the utility to strictly reduce energy usage. These programs do not reduce load in some hours and add load in other hours, as load shifting programs will. Important examples of this class of programs are: incentives for energy efficient lighting, replacement of incandescent bulbs with compact fluorescent bulbs, free energy audits, low-interest loan programs for weatherization, and incentives for the purchase of high efficiency appliances. Energy conservation DSM programs are not likely to be in the best financial interest of a utility unless incentives to the utility are given by regulatory bodies to compensate for revenues lost through DSM. In recent years, a number of states have encouraged utilities to offer energy conserving DSM programs through such incentive methods. In the future, conservation may be found to serve some utilities' financial interest as clean air requirements force electric utilities to place a high value on reductions in pollution from baseload fossil fuel plants [cf.4].

The discussion above is necessarily brief, but it may help some understand the place DSM can take within a utility's portfolio of means to meet its load. The DSM programs identified as examples of each class must be seen as strategically directed at particular end-use demands or at portions of customers classes. No individual program can replace a major power plant. The value of DSM programs arises when the programs are carefully and individually matched to the utility's hourly load to find the least cost method of satisfying customer needs.

IRP and Capacity Expansion

The IRP method provides a framework for the strategic planning needed to match a utility's hourly load with the supply-side and demand-side options available. Figure 1 displays in a general manner a process by which the IRP method can be implemented. It is the model for Argonne's approach to IRP in the Western EIS. The iterative nature - i.e., the feedback loops whereby the energy price and the system marginal cost is adjusted within the process - is an essential key to reaching a balanced plan where demand and supply options compete on an equal basis for a place in the utility's portfolio of DSM programs and plant capacity. Other iterative and integrated approaches to IRP exist [7,8], but the process depicted in Figure 1 meets the needs of the Western EIS.

The process begins by taking estimates of the future values of important regional economic factors (e.g., personal income, factory and commercial floor space, etc.) and energy prices as inputs to a forecast of the system loads. The load forecast without reductions for the impacts of DSM programs is taken as the requirements which the utility needs to meet either with demand-side programs or generating capacity. The forecast needs to be specified as hourly loads extending through the end of the planning horizon.

At the same time as the hourly load forecast is estimated, a forecast of the hourly kW reductions from cost-effective DSM programs needs to be estimated. In Figure 1, this estimate is represented as the DSM forecast. For this estimate, one must determine which DSM programs are cost-effective. Inputs to the cost-effectiveness test are the price of energy and the marginal cost of the system. The price of energy influences consumer choice to participate in voluntary DSM programs and determines the value of revenue lost as a result of DSM programs. The marginal cost of the system places an opportunity cost on the kW reductions each DSM program offers. By bring together the opportunity cost of reductions from potential DSM programs, the value of lost revenue, and other utility and customer costs of potential DSM programs, one can evaluate or test which DSM programs are cost-effective and which are not. The hourly kW reductions from the cost-effective DSM programs are subtracted from the initial load forecast to develop the hourly load which must be met by supply-side resources during the planning horizon.

The next step involves the choice of supply-side options to meet the hourly load requirements. This portion of the process follows traditional utility planning practices for developing a least cost capacity expansion plan. It is followed by a financial model which computes the marginal cost for the system as constituted in the newly devised capacity expansion plan. The financial model also determines the revenue requirements of the utility under the expansion plan and a set of annual prices by customer class which recover the required revenue.

For the IRP method, the important outputs of the financial model are the prices in each year that the utility expects to charge its customers and the marginal cost of the system. These outputs are fed back to the portions of the process which estimate the load forecast and evaluate the cost-effectiveness of DSM programs. The importance of the revised price path estimate should be obvious: if the original energy price estimates were lower than the revised prices, the load forecast would be greater than would occur given the expansion plan and its costs. By allowing a feedback for the price variable, the load forecast can be revised as many times as needed to bring the prices used in the load forecast into line with the prices which meet (in a reasonably close fashion) the required revenue for the expansion plan.

The marginal cost of the system are also part of a feedback loop. Since the marginal cost of the system coming out of the financial model is likely to be different from the marginal cost used to test the cost-effectiveness of the potential DSM programs, it is necessary to test for the cost-effectiveness again. For instance, if the marginal cost after the choice of supply-side options is lower than the marginal cost used to test DSM programs, it is possible that some DSM programs which tested cost-effective on the initial round are not cost-effective given the revised marginal cost. This feedback and retesting of DSM programs provides the opportunity for DSM programs to compete with supply-side options.

The diagram in Figure 1 suggests continuing iterations until convergence of the price and marginal cost paths throughout the planning horizon. In practice, exact convergence is neither expected nor required. The essential characteristic of the process, however, is maintained as long as there is a sufficient opportunity for fair treatment of both supply-side and demand-side options.

Unique Features of IRP in an EIS

Argonne's socio-economic research team for the Western EIS has had to accommodate the special structural requirements of the EIS process within the IRP method. Engaging these unique features has been a challenge, but the effort can serve as a model for future work by others writing an EIS for utility expansion plans. Three features appear unique to applying the IRP method in an EIS: 1) developing capacity expansion paths and cost-effective DSM programs for a number of different EIS alternatives; 2) quantifying in great detail the environmental damage associated with various plant expansion and utilization plans; and 3) including explicitly the socio-economic impacts the region receives from energy development under each EIS alternative.

The National Environmental Policy Act has set up the EIS process to assure that adequate information is developed and made available on proposed actions which could have harmful environmental consequences. To assure the generation of appropriate information, an EIS is structured to present a number of different choice options to decision makers and the interested public. The different options are organized as alternatives which are each separately and thoroughly researched and reviewed. Among the alternatives are a proposed action by the initiating agency, a "no action" or baseline alternative, and all reasonable options which could meet the needs of the initiating agency or the general public. Through the development of many separate alternatives, the EIS process aims to give a wide range of information to policy makers and the potentially affected parties. As a practical matter in an EIS like the one Argonne is writing for Western, the alternatives imply the generation of a number of different expansion paths for the utilities involved. Each of which must be processes through the separate portions of the IRP method described above. The processing is time-consuming and costly. The Western EIS has seven alternatives, each of which must be separately examined. Expansion planning for most utilities require the development of only one least cost plan.

When developing an IRP for most utilities, the environmental consequences of capacity expansion are not a direct and immediate concern. Even with the interest by some public service commissions to determine the social costs of utility plans, environmental issues necessarily are less important within rate cases and construction cases than the matters of financial viability and system reliability. This is not the case in an EIS. Actual and potential environmental damages need to be identified and quantified. For instance, in Argonne's EIS for Western the analysis includes the impacts changes in hydropower operations will have on downstream fish and wildlife; it also examines the potential changes in aquatic geology and recreational land use.

As difficult as quantifying the environmental consequences of each alternative in the Western EIS is the explicit inclusion of socio-economic impacts. In all IRPs economic activity is an input to the estimation of the demand for electricity. Few, however, would include economic activity as an outcome to be examined as a result of planning. Argonne's EIS includes a major study of the changes which will occur to the regional economies under each of the EIS alternatives and IRP expansion plans. The study will include projected changes in personal income, production by industries in the region, employment, and energy prices. Because there is a special interest within the region, Argonne is conducting an impact analysis particularly directed at the consequences the power marketing alternatives will have on recreation and the tourism industry.

These unique features of Argonne's EIS impose additional data, computer processing, and analytical challenges on the implementation of the IRP method. It has been found, however, that these problematic aspects have not diminished the merit of the IRP method, and the fundamental balancing of supply-side options and DSM programs can be maintained even under these challenges.

Conclusions

To summarize, the socio-economic research team at Argonne has found that the IRP method of utility planning has important applications in the EIS process. Although finding the least cost expansion path which balances DSM programs and supply-side options is more difficult when the task is burdened with the requirements of an EIS, the IRP method nonetheless produces the information required for the EIS process and the rational inclusion of DSM programs in utility expansion plans.

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Figure 1

Iterating to Price and Marginal Cost Convergence in IRP