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An Overview of Analysis Tools for Integrated Resource Planning

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AN OVERVIEW OF ANALYSIS TOOLS FOR INTEGRATED RESOURCE PLANNING

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ABSTRACT

Least-cost utility planning confronts utilities with the difficult task of preparing resource plans that use conventional modeling tools in new ways, as in the calculation of avoided costs from production-cost models, and it introduces a new generation of planning tools specifically designed to deal with the complexities of demand-side resource quantification and demand-supply-side integration. In this study, we provide a road map that seeks to illustrate the broad range of capabilities available with current planning models and the major conceptual distinctions among them. We start from a sketch of the major steps in least-cost planning and highlight some of the complexities involved. We then discuss various approximations to this ideal that can be achieved with existing modeling tools. Moving from the most sophisticated approach, which involves the linking of a number of detailed, specialized models, we discuss successively simpler modeling approaches and the compromises they involve.

INTRODUCTION

Well-documented failures in the markets for energy services have lead regulators to consider new planning approaches for utilities.[1,2] These planning approaches, broadly referred to as integrated resource and least-cost utility planning, called for expanded roles for utilities in the provision of energy services. Specifically, they call for increased utility reliance on resources on the demand- or customer-side of the meter. This new planning approach involves substantial modifications and expansions for traditional utility resource plans. From an analytical standpoint, these modifications include the use of conventional modeling tools in new ways, as in the calculation of avoided costs from production cost models, and typically the use of a new generation of planning tools specifically designed to deal with the complexities of demand-side resource quantification and demand-/supply-side integration.

Hirst provides an excellent example of these modeling complexities in his recent description of the Demand and Resource Evaluation (DARE) project of Puget Power and Light: "The DARE final report includes the key elements of an IRP. Alternative load forecasts were developed....Various demand and supply resources were assessed....Different combinations of demand and supply resource were then examined."[3] Models and other analytical tools have value for LCUP only to the extent that they facilitate planning by manipulating data in ways that are meaningful, understandable, and helpful to decision makers. That value stems largely from the conceptual structure provided by a modeling framework. Technically, the structure serves to define the range and manner in which issues can be addressed. Institutionally, the structure promotes the use of a common set of definitions and, as such, can be extremely effective in building consensus during the planning process and in identifying areas for conflict resolution. Use of common data sets also gives staff at many levels of utilities and PUCs a broader picture of the LCUP process.

In the following discussion of models used in least-cost planning, we provide a road map that seeks to illustrate the broad range of capabilities available in current planning models and the major conceptual distinctions among them. Procedurally, we start from a sketch of the major steps in LCUP and highlight some of the complexities involved. We then discuss various approximations to this ideal that can be achieved with existing modeling tools. Moving from the most sophisticated approach, the linking of a number of detailed, specialized models, we discuss successively simpler modeling approaches and the compromises they involve. In all our discussions, emphasis is on the issues raised for LCUP by these compromises and on the sensitive areas they pinpoint.

Our review of LCUP analysis tools is not exhaustive, nor is it to be construed as an endorsement of one vendor's product over another. Accordingly, while these discussions are accurate portrayals of the models, given available reference materials, they cannot account for changes to subsequent versions of these same products, which can differ considerably. The interested reader is advised to contact vendors directly for the latest information about products. The Electric Power Research Institute (EPRI) has prepared a directory that lists over 80 computer models for demand-side management and its integration into resource plans.[4]

INTEGRATED RESOURCE/LEAST-COST PLANNING PROCESS OVERVIEW

The planning approach encompassed by integrated resource and least-cost utility planning and the use of models to implement it represent a marked departure from traditional utility planning methods. Figure 1 outlines the steps involved in traditional utility resource planning, while Fig. 2 outlines those involved in integrated resource planning and least-cost planning. With traditional utility resource planning, demands for future electricity, as determined by a load forecast are fixed prior to the analysis of resource options. Use of an exogenously specified trajectory of future loads essentially excludes non-generation options (such as energy efficiency) as active options for utility intervention. While these options can and should be included as factors in the load forecast, their exclusion from the planning process means the utility only selects from supply-side resources to meet future demands. With integrated resource or least-cost planning, however, non-generation options are explicitly included as options for utility intervention. Consequently, the load forecast becomes endogenous to the planning process.

Another important terminological distinction lies in the differences between "integrated resource planning" and "least-cost planning." Both are often used to describe planning activities that consider demand and supply side options as resources available to meet future energy service needs. Yet there are important differences between these two planning approaches. Table 1 shows both approaches to the previous stylized characterization of traditional utility resource planning.

As seen in Table 1, both approaches differ from traditional utility planning by considering demand as well as supply side options. They differ from each other, however, in specification of the planning objective. Integrated resource planning typically bases planning decisions on an evaluation primarily of direct costs to the utility. As such, the impacts of demand-side options on rates is often an important consideration. The share of demand-side option costs borne by the customer becomes relevant only to evaluations of the willingness of customers to adopt a utility-sponsored demand-side option.

Least-cost utility planning includes a larger ranges of costs in resource evaluation. These costs include not only customer-borne costs, but may include the costs of planning "externalities" (such as impacts on local economic development or the environment) typically not included in traditional or integrated utility planning. Inclusion of this broader range of costs often results

Figure 1
Traditional Utility Resource Planning

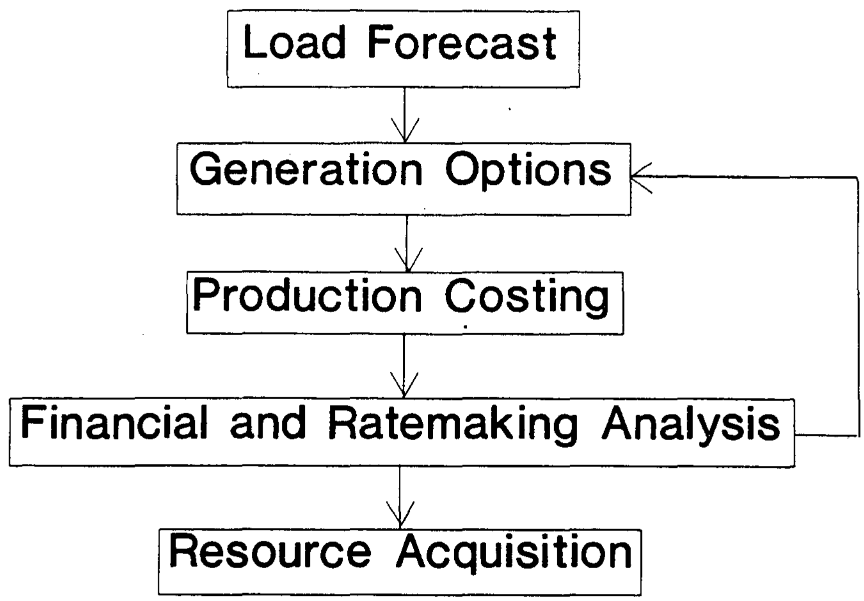
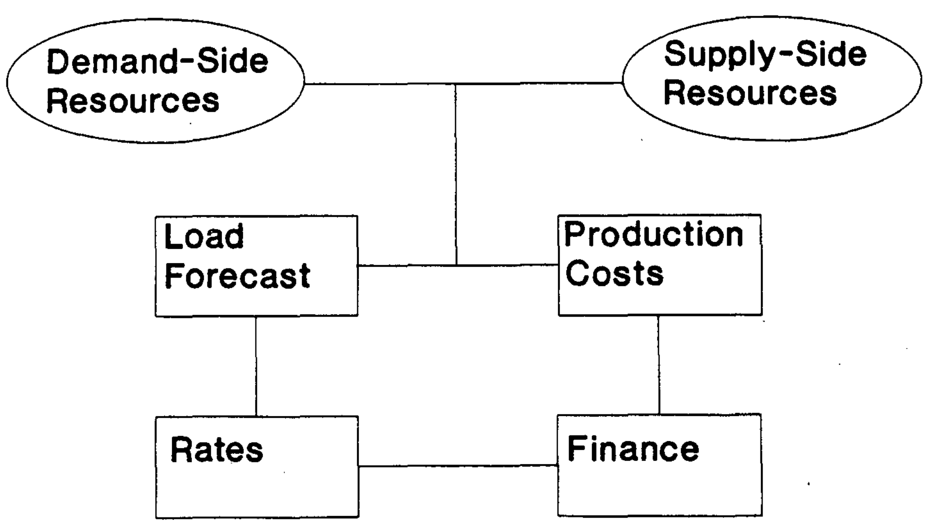


Figure 2
Elements of Integrated Resource Planning



in the need for greater public participation in the planning process. A longer discussion of these differences can be found in EPRI.[5]

Table 1. Comparison of Resource Planning Approaches.

	Traditional Utility Planning	Integrated Resource Planning	Least-Cost Utility Planning
Supply-Side Options	Yes	Yes	Yes
Demand-Side Options	No	Yes	Yes
Planning Objective	Minimize Revenue Requirements	Minimize Revenue Requirements	Minimize Societal Costs

From an analytical or modeling standpoint of direct economic costs, however, both integrated resource planning and least-cost utility planning involve the same methodological steps: load forecasts of energy and load shapes; cost and performance of demand- and supply-side options; consumer acceptance of these options (primarily of those on the demand side); long- and short-run utility production costs; impact on a utility's financial position; and interaction effects between *and* within the above five items.

Several important methodological issues arise in the context of integrating demand-side resources in what has traditionally been a supply-side planning exercise. These issues will form the technical basis for our review of integrated resource planning approaches in the following sections. The issues include: (i) *Consistency between estimation of demand side program load shape impacts and the overall system energy/load shape forecast.* Does the model account for the interactive effects of several programs or the effect of a single program on other components of the forecast? Or does it simply subtract demand side program load shape impacts from a base-line forecast in a way that may overcount or undercount load impacts and their value to the system? (ii) *Integration of demand-side programs into the generation expansion plan.* Are demand-side programs large enough to alter the timing or size of future supply additions? (iii) *The relationship between demand-side programs, load shapes and rate design.* Are demand-side programs large enough to alter retail rates, and, if so, how exactly are rates affected? How do rates, in turn, affect future load shapes? (iv) *Representation of demand-side programs that rely on prices, not technologies to modify demands.* Can the demand forecast reflect the impacts of new or innovative rate structures? (v) *The role of uncertainty in all facets of the planning process.* Can the models used meaningfully capture the range of uncertainty underlying the data used in the planning process?

LINKED, DETAILED MODELS

The most complicated evaluation method for LCUP involves linking the inputs and outputs of individual, detailed models into an integrated process. The method is attractive because the detailed models selected are generally already in use as chief analytical tools for different utility departments. Institutionally, the results from these models will tend to carry the support of their host departments with them.

Generally speaking, there are models for each step of the LCUP process, including load-shape forecasting, generation planning, production costs, financial analyses, and rates. (See Fig. 2) Examples of load-shape forecasting models commonly used in this approach include the EPRI family of sectoral end-use models, consisting of REEPS,[6] COMMEND,[7] INDEPTH,[8] and HELM.[9] Production cost models have been traditionally used by the industry to support generation expansion planning. Some of the most well-known of these models include Energy Management Associate's PROMOD III,[10] Stone and Webster's EGEAS,[11] and the Environmental Defense Fund's ELFIN.[12]

Published examples of the model linkage approach include EPRI's case study of the Sierra Pacific Power Company using EPRI end-use forecasting and integrated planning models and a private vendor generation planning model,[13] and work at LBL in which the authors examined the financial impacts of appliance standards on individual utilities.[14]

The primary difficulty of the model-linking approach stems from the fact that the models were not originally designed to be linked. Instead, they were designed to stand alone, each with its own unique sets of inputs and outputs and corresponding data conventions. Consequently, the analyst must exercise substantial judgement to ensure that data are consistently translated from one model to another. A potential benefit of this judgement is that the process of linking model inputs and outputs will require more explicit review and analysis of the data used in the analysis. In the work by LBL previously cited, an hourly load shape model was employed to translate forecasts of annual electricity requirements into hourly load shapes by end use, but these residential class load shapes then required further analysis for translation into impacts on system-wide loads. Moreover, the impacts on system loads required compression and translation into the seasonal load duration curve format required by the production cost model.

Another issue for the model linkage approach is that the data requirements for individual models can be significant. Table 2 lists data requirements for the EPRI COMMEND model, which is an end-use model for the commercial sector. End-use forecasting models, in particular,

Table 2. COMMEND Data Requirements.[15]

Market Data	Forecast Data
Floor Stock - 10 building types Energy Intensities - 8 end uses Average Fuel Shares - 3 fuel types Marginal Fuel Shares Average EUI Values Marginal EUI Values Technology Curves Daily Fractions Load Shapes	Real Prices Economic Growth Parameters

are constrained largely by the inability of the analyst to obtain the detailed data that the model structure is capable of processing. This situation is largely due to the fact that utilities have spent many years compiling information on supply-side resources, while efforts to compile comparable information on the demand-side remain in their infancy. As a result, default values must be used whose consequences are uncertain. As with the previous issue, trade-offs are required, driven in this case by the need to balance the cost of obtaining large amounts of data required by the analysis against the comprehensiveness of the analysis.

INTEGRATED PLANNING MODELS

Recently, a new class of least-cost planning models has been developed. These "integrated" planning models incorporate important elements necessary for comprehensive treatment of demand- and supply-side measures. The distinctions are not clear-cut; indeed, some resource planners may refer to integrated models as screening tools because they are less detailed than the state-of-the-art models for which integrated models can be substituted.

The overwhelming advantage of these models is that they perform in a single piece of software aspects of analyses generally found in more complex, detailed models. In the model linkage approach, a major challenge is to ensure data compatibility across independent models. The time-consuming process of making these linkages, typically by hand, represents a significant constraint on the ability of analysts to perform multiple analyses, as might be required in an evaluation of important uncertainties. With integrated-planning models, major linkages are embedded in the simulation and made transparent to the user. The most important of these linkages is between the specification of the demand-side loads and the subsequent effects on production costs. Consequently, many scenarios or sensitivities can be evaluated very quickly compared to the model linkage approach.

Examples of commercially available integrated planning models include Lotus Consulting Group's UPLAN,[16] Energy Management Associate's PROSCREEN,[17] Decision Focus and Electric Power Software's LMSTM,[18] EPRI's MIDAS,[19] A. Ford's CPAM,[20] and Systematic Solutions' ENERGY 2020.[21]

We use two criteria to distinguish integrated planning models from screening tools (which are described in the following section). First, integrated planning models usually permit the user to specify the end-use structure of demand in great detail. The models typically accept hourly load shapes that can be combined individually from the bottom up or subtracted directly from a system total load shape. Second, they also usually feature dynamic simulation of the production cost impacts based on these load shapes. These features make integrated-planning models an attractive middle ground between time-consuming linking of independent detailed models, and the great sacrifices in detail required by simpler screening tools.

The benefits of integration, however, can be compromised by the technical and institutional costs of a modeling approach that falls between these two extremes. Technically, integration results in some loss of detail at each step in the analysis. Despite substantial data requirements, simplifications are often unavoidable, and model results will always be evaluated relative to those produced by the more detailed models. Thus, the models often need extensive benchmarking and calibration. In a recent study of thermal energy storage in the Pacific Gas and Electric (PG&E) Company service territory, LBL researchers devoted significant project resources to calibration of EPRI's LMSTM model to production cost results from PG&E's in-house model.[22] Institutionally, these calibration efforts are essential to give model results credibility.

Several methodological issues must be evaluated in judging any integrated planning effort. We introduce several of them in this section because they are often suppressed in uncritical use of integrated models. Nevertheless, these issues are no less significant for the simpler screening tools to be described in the following section.

The first issue deals with consistent and meaningful treatment of demand-side programs in developing system-wide load shape impacts. Often, demand-side programs are represented as reductions in load from a system load shape. This technique can double-count load savings from successive, yet highly interactive demand-side measures. A chief advantage of stand-alone, end-use forecasting models is their ability—in principle—to treat demand-side measures consistently.

The in-house integrated planning system developed by the Northwest Power Planning Council (NWPPC) is exemplary in providing a consistent framework for utility planning. The NWPPC model forecasts differing levels of future demand-side management activities based on forecast changes in regional economic development.[23] In this rare example, interactions between various demand-side management activities are made explicit and they are also linked consistently to underlying regional trends.

A second issue to judge in an integrated model is the model's ability to represent the load shape impacts of demand-side measures easily. Many integrated-planning models offer sophisticated load shape handling and modification capabilities. For example, the EPRI LMSTM model offers extensive load shape data capabilities. Up to 48 end-use customer class combinations can be treated. Each is represented by 16 daytypes consisting of 24 hourly loads per daytype.[24] These capabilities often outstrip the data available to represent these measures meaningfully. Without reliable data on the performance of demand-side measures, these capabilities are not useful. More importantly, in the absence of critical oversight, use of these capabilities can produce misleading results.

The third issue for judging an integrated model is the treatment of demand-side measures in generation planning decisions. For many integrated planning models, the generation expansion decision is specified exogenously by the user. Although this treatment may be warranted for demand-side measures with small load shape impacts, serious least-cost planning efforts require consideration of large demand-side impacts that defer or displace power plants. Determination of the appropriate deferral period is not straight-forward.[25] Often, the user must implement these necessary modifications to a base case generation expansion plan by hand; the program will not alter a supply plan automatically. Where optimal generation expansion capabilities are offered by a model, the user must take care to ensure correct specification of the objective function and its constraints. For example, an early demonstration of the optimal generation expansion capabilities of the EPRI EGEAS model, based on data representative of PG&E, produced a plan that called for immediate construction of 16 baseload nuclear units in the first year of the analysis period.[11] This implemention clearly did not reflect the relevant financing and political constraints faced by PG&E.

The fourth issue for integrated models covers the effects of demand-side changes on utility rates and the effect of these rates on future electricity demands. The effects of demand-side programs on utility rates (and finance) are generally treated simplistically. On the one hand, forecasting ratemaking is difficult because of the need to forecast future cost-of-service relationships for all customer classes, and the need to forecast an inherently unpredictable regulatory process. On the other hand, some forecast of future rate levels and structures is crucial to forecasting future demands for electricity. In general, most integrated models, despite the rich detail available to specify system loads, do not provide for sophisticated treatment of the factors that influence these loads (such as time-differentiated prices for electricity, income, demographic change, etc.). Typically, these influences must be captured in a detailed energy forecasting model and translated into load shapes for the integrated planning models.

Of course model capabilities do not guarantee utilization in a planning process. For example, in a recent study for a gas pipeline for the Northeast a system dynamics program for integrated resource planning was used. The model incorporates detailed interaction between supply- and demand-side activities, including the feedback between prices and subsequent demands. However, the project did not rely on a full implementation of the electric and gas utility supply sectors of the model. Instead, externally supplied electric and gas prices were used. In other words, the detailed interaction capabilities of the model were by-passed and replaced by a static model in which future demand-side and supply-side activities could not have any impact on future rates.

DSM SCREENING TOOLS

DSM screening tools address the problem of the multitude of options available on the demand-side. Detailed analyses of every conceivable option or combination of options would require substantial effort (using the model linkage approach or an integrated planning model). The marginal benefit of these efforts may be limited because typically only a small number of options will make it into the final least-cost optimum.[†,26]

Hence, the goal of these models is to provide a "first-cut" ranking of DSM options in order to identify the most clearly beneficial measures. The logic is that, by simplifying many of the assumptions and by suppressing many of the details required by a more in-depth analysis, one can rapidly identify the most promising options. A related reason for using these models is that it is usually quite easy to perform sensitivity analyses of key assumptions. In general, the outcome of analysis using screening tools identifies the programs that are worth further study in greater detail. Examples of well-known DSM screening models include Synergic Resources Corporation's COMPASS,[27] EPRI's DS Manager,[28] Barakat, Howard and Chamberlin's DSM Planner,[29] and the American Public Power Association/EPRI's RDSM.[30]

Screening tools, by our definition, rarely include simulation capabilities. The characteristics of options (e.g., performance, cost, market penetration), and generalized yardsticks for use in valuation (e.g., marginal energy costs) are specified exogenously by the user. Typically, these

† See Hirst[26] for a review of the complexities inherent in creating viable utility conservation/load management programs.

data are developed from outputs of more detailed models. In essence, then, most screening models are often no more than sophisticated spreadsheets, which consistently translate user-defined inputs into standardized cost-benefit perspectives. Consequently, meaningful use of these models requires careful scrutiny of the inputs by the user.

As a result of the model's spreadsheet qualities, interaction effects are usually ignored. Thus, use of such a screening model, means that the impact of a single demand-side measure will probably not account for the effect of another, logically related one. For example, a tighter building shell will reduce cooling loads, and so reduce the potential energy savings from an efficient air-conditioner meeting these lower loads; screening models generally will not be able to account for these effects. On the supply-side, the analogous example is the inability of non-dynamic models to capture the effect of increasing amounts of conservation to reduce short-run marginal costs or, alternatively, to defer or cancel future plant construction.

The benefit of ignoring these subtleties is that the models are often user-friendly. Many models are available for personal computers and feature colorful, easy-to-use, menu-driven screens. Since the number of calculations performed is limited, these models often feature quick turn-around times that make them ideal for screening many programs, as well as testing the sensitivity of the results to changes in key assumptions. In the initial, strategic phases of an analysis of demand- and supply-side options, these features are highly desirable. The data requirements for this class of models are typically straightforward; though, they can be large.

The limitation of these models is the reliance on a necessarily simplified, non-dynamic characterization of a utility and its customers. This limitation can, however, be avoided in three ways. The first is to avoid placing undue emphasis on detailed quantitative results but to focus instead on general trends that can be addressed in detail by more sophisticated techniques. The second is to exercise substantial critical judgment in developing the inputs for use in these models. The third is to perform extensive sensitivity analyses on key inputs.

CONCLUSION

At this time, the inherent limitations and relative accuracy of available modeling tools are not well understood. For example, no comprehensive comparison has been performed between the major integrated resource planning models that are widely used in the industry.† Even less understood are the differences in results that alternative applications of existing and new modeling tools might yield in the expanded, LCUP form of utility resource planning.

†However, The California Public Utilities Commission has recently sponsored limited review of major production cost models. [31, 32]

More importantly, these problems are overshadowed by the even larger uncertainties in the input data required by the models. The data required by most models are more detailed than most currently available data, which often leads to use of default values or, essentially, judgment calls by the model user. The cumulative impact of these values is difficult to evaluate.

A related problem is the need in sophisticated least-cost planning efforts to link a number of models with each other. Extensive calibrations may be needed to make models compatible with each other, both in terms of data detail and formats. Utilities that have invested in a particular production cost model or other expensive planning tool may find themselves confronted with the need to make large additional investments in staff training, data generation, and calibration. The appropriate linking of models and their associated data sets to arrive at least cost integration is another area where good judgment is required and the impacts of methodological choices is not sufficiently understood.

Utilities must contend with these uncertainties while making high-stake planning decisions. There was no world of perfect information in the past, and it is unlikely that there will ever be one. It is our hope that this limited overview of integrated modeling tools will contribute to an informed dialogue between utilities and their PUCs that will ensure the constant improvement of least-cost planning procedures. Improvement may not just mean a move to ever greater detail and comprehensiveness, but also the development of acceptable approximations; the effects of which are understood by all parties and which keep filing requirements tractable.

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