PERSPECTIVE: LEAST COST PLANNING
An Old Idea Whose Time Has Come

This issue of POWER TECHNOLOGY departs from past issues and is devoted to a single topic, "Least Cost Planning." This newsletter explores that question and points out that this "new" approach includes most of what the industry has practiced almost from its inception, but with additions to fit today's and tomorrow's conditions better than classical approaches. This article by Burke and Puntel points out that least cost planning seeks to recognize a variety of costs and benefits as seen by different stakeholders - not just cents/kWh. Non-traditional options are also considered, which is why "integrated demand-supply planning" is also used to describe the same body of concepts. And uncertainty is recognized as a key issue.

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PTI has been doing least cost planning for almost two decades. We believe that the new concepts which utilities are finding useful add significantly to the value of these analyses. These articles are intended to offer ideas you can use in today's environment.
DEMAND-SIDE OPTIONS — ISSUES AND MODELING PROBLEMS

W.R. Puntel,
Senior Engineer

A key element of the least cost planning concept is the integration of supply-side and demand-side options. Traditional planning methodologies have evolved to satisfy modeling requirements for the turbine/generator options that are normally considered as supply-side alternatives. Demand-side options also must be modeled. These include:

- direct utility control of electric water heaters and central air conditioners,
- energy storage devices used with space heaters and air conditioners,
- energy use modification through rate incentives such as time-of-day rates,
- direct control of commercial, industrial, and agricultural equipment through load interruption agreements, and
- energy conservation devices and equipment.

One problem with integrating these options is that they often have different characteristics than the supply-side alternatives. For example, direct control of appliances can shift energy consumption from peak hours to off-peak hours. Unfortunately, traditional study methodologies frequently use approximate load duration models that do not capture the chronological impact of these shifts.

The procedures for integrating demand-side options into the planning process fall into two broad categories:

- incorporation into the load forecast, and
- simultaneous evaluation of supply-side and demand-side options.

The second approach is best suited to situations where the decision to incorporate a particular demand-side option has already been made. Implementation of this type of approach involves a procedure iterating between forecasts of load behavior and traditional production simulation studies. After several iterations, a demand-side management plan can be formulated that provides the most favorable response.

The second approach is more suitable when supply-side and demand-side options are to be compared on a competitive basis. To perform a fully integrated study, the demand-side models must be consistent with the capabilities of the study techniques. Often, the traditional modeling tools have to be modified or augmented to accommodate demand-side alternatives.

Demand-side parameters do not always fit cleanly within traditional definitions. For example, should the costs for installing load control devices at a customer's location be treated as a capital investment or an expense? Some demand-side programs offer incentive payments to customers to encourage participation. Other programs require customers to pay for the installation of receivers and switches. These parameters are not traditional "revenue requirements" but must be considered to make a fair comparison with other options.

A major problem has to do with determining the capacity, reserve, and reliability credit for demand-side alternatives. For example, a program that involves utility controlled air conditioner cycling might produce a total peak demand reduction capability of 100 megawatts for one utility. However, since this reduction would be available only on the hottest days of the year, is a 100 MW gas turbine really an equivalent option? Air conditioner cycling produces an increase in demand later in the day when air conditioners are released from control. This characteristic may invalidate the use of daily peak load models for reliability evaluations.

In previous studies, PTI has addressed these issues by performing detailed, capacity equivalence studies outside of the main framework of the planning simulation. These studies used suitable reliability models to determine the reliability equivalence between supply-side and demand-side options so that the results would be incorporated into the main planning studies.

The following figure shows the outcome of one analysis comparing direct control of central air conditioners with conventional combustion turbine peaking capacity. Two curves are shown, one for a control program that resulted in a peak load reduction of 159 MW and another that resulted in a 350 MW reduction. The Capacity Equivalent Factor, on the vertical axis, represents the combustion turbine capacity, in per unit of peak load reduction capability, that produces the same level of reliability as the load control program. The horizontal axis plots the number of days during the summer season in which load control action was assumed to be applied. Note that for this study, the reliability value of air conditioner control depended on the number of days it was used. This may be an uncertain parameter during the planning stage.

Capacity Equivalence of Air Conditioner Control

Demand-side options also bring other uncertainties into the picture. Customer response to a particular demand-side option may not be as favorable as anticipated. Equipment installed at a customer's location is subject to tampering and may not be available when needed. Little historic data may exist to justify the failure and maintenance assumptions used for demand-side equipment. Many of these uncertainties can be reduced by carefully planned customer relations' programs and comprehensive experimental field tests. As more organizations address these issues, the information base will broaden and additional techniques will become available. Until then, planning must proceed with the data available — but with due recognition of its uncertainties.

TRADE OFF/RISK METHODS FOR RESOLVING DIVERSE OBJECTIVES

R. Mukerji,
Analytical Engineer

H.M. Merrill,
Manager, Planning

Elsewhere in this issue, Burke and Puntel define the least cost planning problem and point out the difficulties in modeling demand-side options using conventional planning methods. TRADE OFF/RISK methods are used to solve planning problems that have conflicting objectives in the face of uncertainty. In Least Cost Planning there is usually no single objective that is acceptable to all concerned groups and individuals (e.g., the utility, the Public Utilities Commission, the rate payer, the environmentalist). Therefore, plans need to be considered in a framework that recognizes the trade offs between conflicting objectives and ensures that the plan chosen will be flexible enough to embody good trade offs over the range of uncertainties.

The methods described in this article are ideal for dealing with:

- multiple conflicting attributes (objectives),
- uncertainties, and
- integration of results from a variety of models.
Trade-offs are illustrated in Figure 1. Each asterisk (*) is a different plan. There are two conflicting objectives, minimize reserve deficiency and minimize revenue requirements. For high revenue requirements, reserve deficiency is low (high reliability), and vice versa. The plans near the knee of Figure 1 represent the best trade-offs between revenue requirements and reliability.

Revenue requirements and reliability are the two attributes that are analyzed in Figure 1. If more attributes are also to be considered, the trade-off curve becomes a multi-dimensional trade-off surface which cannot be drawn on two-dimensional paper. The best plans are the ones which are near the knee of this multi-dimensional surface.

![Figure 1. Sum of Annual Reserve Deficiencies (MW below Reserve Obligations) Versus Present Worth of Revenue Requirements, 20 Year Horizon](image)

Figure 1 is deterministic: load growth, fuel prices, etc., are considered known. When uncertainties are considered, the following distinction is very important:

- The effect of uncertainties on the attributes is not the issue.
- The issue is the effect of uncertainties on the decision.

This distinction is subtle and is often overlooked. It means that it may be irrelevant (as well as impossible) to find a plan so flexible or robust that its revenue requirements, reliability, and other attributes are unaffected by uncertainties like load growth and oil prices. What robustness or flexibility really means is that a decision looks good over a range of outcomes or values of uncertainties.

How is this incorporated into trade-off analysis? Uncertainties are handled by seeking robust plans (plans near the knee of the trade-off surface over many or all variations in uncertain parameters). Figure 2 is an example. Twenty-two plans are shown in terms of two attributes, revenue requirements and $SO_2$ emissions, for high and low extremes of load growth. The uncertainty in load growth has a great effect on the attributes. Nonetheless, the plans near the knee at high load growth are also near the knee at low load growth — they are robust.

![Figure 2. Present Worth of Revenue Requirements Versus $SO_2$ Emissions for 22 Coal Conversion Plans](image)

Figure 2 is a best case in the sense that some plans are robust: they are near the knee of the trade-off curve over the range of values of the uncertainty. Often, there is no plan that is robust for all values of uncertainties. When this occurs, the planner can analyze the exposures and risks that various plans suffer if adverse outcomes of the uncertainties materialize. He can also seek ways to modify or hedge his plans against unfavorable outcomes, thus increasing their robustness.

Incidentally, uncertainties are usually modeled in one of two ways. A probability structure may be assumed, where a likelihood is assigned to each possible value of the uncertainties. An alternative, equally legitimate, approach is to model uncertainties as unknown but bounded: upper and lower limits are established, but with no assumptions about probability distribution functions. Either modeling approach can be used in the TRADE OFF/RISK methodology.

TRADE OFF/RISK methods have been used in a variety of studies. Some options that have been considered are:

- Size and timing of new coal plants
- Coal conversion
- Various scrubber technologies
- Incorporating combined cycle plants
- New hydro and geothermal plants
- Encouragement of cogeneration and third-party generation
- The amount of Canadian power to be purchased
- The level at which a life extension program is to be implemented
- The level at which a load management program is to be pursued
- The network reinforcement strategies to be used

Uncertainties which have been of concern to the decision makers include:

- Load growth
- Fuel prices
- Cost of capital
- In-service date
- Availability of purchasable power
- Customer response to load management initiatives
- Hydro conditions

The attributes of interest to the various groups (utility, ratepayer, public commissions) include:

- Financial and Economic Attributes — e.g., new capital requirements
- Environmental — e.g., $SO_2$ emissions, new transmission right of way required, etc.
- Revenue requirements
- Reliability — e.g., loss of load probability and reserve requirement
- Dependence on various primary energy sources

Combinations of different values for the options identified produce different plans. Different values of the uncertainties produce different futures. For a particular combination of a plan and a future each of the attributes identified may be evaluated using a corporate model, a production cost program, a multi-area reliability program, etc., as appropriate.

The TRADE OFF/RISK methodology involves four steps:

- **Step 1** A few (perhaps 50) scenarios (combinations of plans and futures) are chosen by the planner. Simulation runs are made using available models to determine the values of the attributes identified.
- **Step 2** This handful of simulation runs is expanded into a large data base using interpolation techniques.
- **Step 3** Mathematical techniques are used to evaluate tradeoffs and robustness, identifying a few highly attractive plans from the expanded data base.
- **Step 4** Planning judgment is used by the decision makers in making the final selection of the best plan from among these. The TRADE OFF/RISK methodology is uniquely tailored to suit the least cost planning process as it:
  - Provides a mathematically sound method to find the best tradeoffs among conflicting attributes;
  - Is capable of identifying the most robust plans in an environment of massive uncertainty; and
  - Makes it possible to analyze a whole gamut of scenarios, using the results of relatively few simulation runs, and integrating data from a variety of sources.
WHAT IS LEAST COST PLANNING?
(Continued from Page 1)

The Electric Utility Rate Design Study was a major turning point in looking at non-traditional planning approaches. Initiated by the National Association of Regulatory Utility Commissioners (NARUC) in late 1974, with major contributions from utilities, it included topics such as load research, price elasticity, and cost-benefit analyses.

In the late 1970's an increased public awareness and concern for energy resources led to the popularization of the phrase "Least Cost Planning." A review of the articles written on this subject reveals an interesting fact—a none of them define how one goes about calculating the cost to be minimized by a least cost plan. The interests of ratepayers differ from the interests of shareholders which, in turn, may differ from the concerns of other elements of society. The various stakeholders view "cost" from their own points of view. This Least Cost Planning perspective is essentially an evolutionary form of integrated planning that places greater emphasis on the cost of energy services to the customer and incorporates societal sensitivities.

What, then, does the concept of least cost planning involve? The answer is that it involves many issues that characterize the interests of the various stakeholders. These include:
- consideration of supply side and demand side options on an equivalent basis, or a so-called "level playing field."
- balancing the cost of providing reliable service with the value perceived by the customer.
- identifying critical uncertainties and determining their impact on a plan's attractiveness. Plans that are favorable over a wide range of uncertainties are robust.
- recognizing the impact that rate increases have on future demand. A reality of the 80's is that large rate increases may result in the loss of energy sales in the future.
- balancing costs for various customer classes so that one group does not subsidize another.
- including "hidden" costs (i.e., externalities) which might impact a broad base of society. Examples include the cost of nuclear fuel waste management or the costs of countering the impact of power plant emissions.

In this framework, it is not possible to define a single, quantifiable cost function that is both meaningful and embodies all of the factors important to the various stakeholders. The main goal of least cost planning is to identify those plans that provide the best compromise or trade-offs among the diverse objectives, recognizing realistic levels of uncertainty. This leads to the identification of robust plans that provide the most favorable balance among "costs" and risk. In a sense, the term "least cost planning" is a misnomer. The concepts that it encompasses might be more accurately described by a phrase such as "global impact planning" or "best compromise planning."

These concepts are important and many utility and regulatory organizations are already including them in their planning processes. Northeast Utilities, for example, has established a planning framework that incorporates an integrated assessment of both demand and supply side options and is responsive to the total demands for energy services within their area. The planning process incorporates flexibility and consistency in its effort to explore trade-offs among the alternatives. The result is a strategy that balances the utility, investor and public policy objectives.

Some utilities are exploring load management resource options such as real time pricing (Pacific Gas and Electric) and residential demand subscription service (Southern California Edison). Combined with increased renewable and cogenerated resource options, load management allows utilities to develop integrated, flexible resource plans.

Various state regulatory bodies have incorporated, or are considering adoption of least cost planning procedures. In Wisconsin, the Public Service Commission has established a regular, formalized planning procedure that includes plan reviews and approvals based on economic, environmental, health, safety and engineering considerations. The Michigan Public Service Commission includes consideration of both traditional and non-traditional options, full integration of supply and demand side alternatives and a selection of options based on a range of economic criteria defined from a societal perspective.

The California Public Utility Commission defines three tests which help to identify least cost plans. These are (1) the utility least-cost test (the traditional revenue requirements approach), (2) the rate impact measure test (which is defined to show the rate impact of various resource options), and (3) the social equity test (formulated to capture hidden costs which result, for example, from tax subsidies).

It is evident that to satisfy the above least cost planning objectives, traditional planning approaches must be expanded to include demand-side options, uncertainty, and value of service attributes. Methodologies must be utilized that clearly reveal the trade-offs that exist among the diverse and sometimes conflicting attributes or measures of goodness. These methodologies must be able to identify the uncertainties which are critical to the selection process and the degree to which the favorability of plans is dependent on the outcome of uncertainties.

Least cost plans can be developed through an iterative process that rigorously evaluates demand and supply-side options (see Figure 2). The modeling effort establishes the planning criteria (attributes) for each alternative. Formulating a long term strategy from these alternatives can be confidently done only after the proper consideration of risk which results from uncertainty in the modeling process. Critical modeling parameters such as load growth, demand-side penetration/effectiveness, interest rates, and the regulatory climate must be evaluated for all futures. Risk minimization, through the selection of robust plans, promotes maximum strategy flexibility. While selected plans may not be optimal for any single future, they are good plans in most futures and balances the interest of all stakeholders—ratepayer, stockholder, and society.

Figure 2. The Least Cost Planning Process

QUICK CORPORATE MODELS FOR INTEGRATED SUPPLY/DEMAND STRATEGIES
(Continued from Page 1)

- What are the avoided energy and capacity costs associated with various supply/demand options?
- What is the most attractive pricing and timing of long term contracts for capacity and energy purchases and sales?

For example, the figure shows the effect on earnings per share for changes in load growth that might be the result of vigorous conservation or load building programs. The utility being modeled presently has significant excess capacity. Even in the high load growth case no new major construction is required until beyond the horizon. The calculated earnings include the effects of sales of excess power to neighboring utilities as well as of long term take or pay contracts. A heavy construction program in the early years and a one-year regulatory lag contributed to the decline in earnings per share shown on the graph. 

(Continued on Page 5)
Quick Corporate Models for Integrated Supply/Demand Strategies

(Continued from Page 4)

A New PTI Short Course . . . Least Cost Planning: Integrating Supply and Demand

Integrated planning, while not a new concept to utility planners, is becoming more important due to the increasing availability of demand management data upon which market penetration and effectiveness forecasts can be based. Alternative strategy development can now account for the contribution of load cycling, thermal storage, alternative pricing, and conservation programs to serving projected load.

The "Least Cost" aspect of electric planning is also not new to utilities. Satisfying forecasted load, while minimizing the present worth of revenue requirements needed to do so, has long been the conventional approach. New least cost criteria are evolving which will be used as measures to assess the merits of alternative utility plans. These criteria will not be easily quantifiable using "LOLP" or "present worth" terms to which utility planners are accustomed. Essentially, without the ability to reduce to consistent units (MW's or $'s), the conventional decision analysis approach becomes quite complicated.

In response to expressed industry need, a new short course has been developed which will focus on integrated electric planning under uncertainty with conflicting multiple objectives. Using "least cost" criteria, "robust" strategies can be identified to the satisfaction of all stakeholders — the ratepayer, the stockholder, and society as a whole.

The course addresses the planning process, technology options, research and marketing, modeling, and analysis and decision methodologies to support integrated resource planning strategy development.

The course is intended for utility planners, regulatory commission staff, or state energy planning personnel who have responsibility for data development, data analysis, and strategy formulation in support of long range integrated electric resource planning.

Three presentations have been scheduled in 1987: April 27-29 and November 16-20, both in Schenectady, NY, and May 13-15 in Madison, Wisconsin.

Least Cost Planning Experience

Power Technologies has long supported the utility industry and research organizations in electric planning. Some of the more unusual least cost planning work we have done over the years include:

1977 Potential Cost Advantages of Peak Load Pricing

Identification of special data requirements and demonstration of a methodology for analysis of the potential benefits of peak load pricing. Economic criteria were developed to support cost-benefit analysis in a test case with Northern States Power.

1980 Study Cost Benefit Analysis of Load Management Options

Development of methodologies to identify the costs and perform cost/benefit analysis of load management options. Reliability, cost and operating parameters were considered in a test case where load cycling and thermal storage options were selected to satisfy a portion of the capacity requirements for a 15 year planning period.

1982 Load Management Cost Effectiveness Studies

A comprehensive assessment of the impact of residential direct load control on the expansion plans of three California utilities. Reliability and revenue requirements were considered for alternative resource plans with and without the lead management options.

1982 Battery Storage Evaluations

Study of use of batteries as a peak-shaving device. Major issues included uncertainty in peak demand growth, costs, and effectiveness of the batteries.

1983 Strategic Studies for "Electricity Factories"

Market assessments, development of pricing strategies, evaluation of risk associated with building nuclear plants (in a foreign country) as non-utility "electricity factories" rather than utility power plants.

1985 Demand Side Management Effects on T&D Design/Operation

Identification of the critical technical and economic issues that impact the transmission and distribution system resulting from increased load management.

1985 Economically Efficient Allocation of Access to the T&D System

Four constraint scenarios were assessed with attention given to cost recovery, generator incentives, incremental costs, load growth dynamics, the regulatory and economic environment.

1985 Quick Corporate Model

Development of a very flexible corporate model that is ideally suited for least cost and strategic studies.

1986 Uncertainty and Risk Analysis in Electric Resource Planning

Development of a methodology to support electric resource analysis with multiple objectives and uncertainty. A framework for decision making is presented which represents an organized approach to identifying "best compromise" alternatives from which resource strategies can be developed.

1986 Various Analyses for the "Strategic Growth Task Force"

Assistance to a major utility's efforts to achieve orderly, planned growth. Issues evaluated included marketing, pricing, achievable and optimal load factors, and cogeneration.

1986 Power Plant Life Extension

A study of the barriers and incentives to overcome the barriers to life extension of fossil and hydroelectric generation facilities.

1987 Wheeling Project — Spot Pricing Program

A project designed to evaluate wheeling rate behavior, PTI will support the development of the model and will validate the model in two demonstration applications.

Beginning with this issue, A.J. Wood will be editing Power Technology. If you have any questions about the articles in this newsletter, or in any past or future issues, please contact him. Questions concerning PTI courses should still be directed to B.E. Gnat.
ORGANIZATION CHANGES

Donald N. Ewart joined PTI in January as the manager of the Consulting Services Department. Don is taking the position vacated by F. Paul de Mello who is now a Principal Consultant. Don is well known in the power industry, having worked for the General Electric Company over 32 years. His most recent assignment there was as the manager of Transmission and Distribution Engineering in Schenectady. He is a Fellow of the IEEE and is currently Chairman of the Fellows Committee of the Power Engineering Society. He will be responsible for all of PTI's consulting engineering activities in generation, transmission, distribution, and industrial power systems, as well as educational programs.

Paul de Mello retains the title of Vice President and joins the group of PTI Principal Consultants. He will continue to work actively with the Consulting Services Department and take care of special assignments for the Company.

Charles W. Moskov joined PTI in March as Manager of Sales. This is a new position in the company in the Technology and Market Development Department. Charlie has been in the power industry for 29 years, since starting as an engineer with PSE&G in 1958. After 14 years in various assignments there, he joined the General Electric Company where he served as Manager of Program Development for product departments, laboratories, and application engineering departments in Philadelphia, Pittsfield, and Schenectady. He will be responsible for the sales and development of new projects on a company-wide basis.

SHORT COURSE SCHEDULE

The following courses will be presented at PTI offices in Schenectady, N.Y.

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<tr>
<th>Dates</th>
<th>Course Title</th>
<th>Tuition (per participant)</th>
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<tr>
<td>April 21-23, 1987</td>
<td>Dynamic &amp; Static Thermal Line Rating Methods</td>
<td>$850</td>
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<tr>
<td>April 27-29, 1987</td>
<td>Least Cost Planning — Integrating Supply &amp; Demand</td>
<td>$850</td>
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<tr>
<td>May 4-8, 1987</td>
<td>Power System Planning Techniques</td>
<td>$1000</td>
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<tr>
<td>May 11-15, 1987</td>
<td>Dynamic &amp; Control Analysis Techniques</td>
<td>$950</td>
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<tr>
<td>May 19-22, 1987</td>
<td>SVCs in Utility &amp; Industrial Systems</td>
<td>$850</td>
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<td>June 2-4, 1987</td>
<td>Cable &amp; Accessory Failure Analysis</td>
<td>$850</td>
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<td>June 10-12, 1987</td>
<td>Power System Telecommunications</td>
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<td>September 14-18, 1987</td>
<td>Power Plant Performance</td>
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<td>September 21-25, 1987</td>
<td>Underground Cable Systems</td>
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<td>October 5-9, 1987</td>
<td>Power System Scheduling &amp; Operation</td>
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<tr>
<td>October 14-16, 1987</td>
<td>Cable and Accessory Failure Analysis</td>
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<td>October 19-22, 1987</td>
<td>Transmission Reliability Assessment</td>
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<td>October 26-30, 1987</td>
<td>Transmission Line Upgrading</td>
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<tr>
<td>November 4-6, 1987</td>
<td>Industrial Power System Harmonics &amp; PF Improvement</td>
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<tr>
<td>November 16-20, 1987</td>
<td>Least Cost Planning — Integrating Supply &amp; Demand</td>
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<td>November 16-20, 1987</td>
<td>HVDC Transmission Systems</td>
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<td>November 30-December 4, 1987</td>
<td>Power System Planning Techniques</td>
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<td>December 7-11, 1987</td>
<td>Industrial Power System Engineering</td>
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<td>December 7-11, 1987</td>
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SPECIAL PRESENTATION

Madison, Wisconsin

May 13-15, 1987 | Least Cost Planning — Integrating Supply and Demand | $850

For further information or registration contact:
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