

SIDE-STEPPING THE ADDER: PLANNING FOR LEAST-SOCIAL-COST ELECTRIC SERVICE

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ABSTRACT

Over the past decade the Integrated Resource Planning process has assumed a central role in calculating the future structure of our electric service industry. The goal of least-cost planning, originally intended to reduce costs by incorporating a broader range of resources—supply and demand, as well as utility and non-utility—has expanded to also include complex and often controversial environmental and competitiveness issues. This shift in goals from least-(direct)-cost to least-social-cost electric service has placed a significant informational burden upon the planning community in how they evaluate resources. The externality debate is a prime example of this burden, where—to address our relative lack of knowledge of the consequences related to residual pollutant emissions—the industry has, in part, turned to value-based in addition to cost-based evaluation techniques. Reliance upon value-based techniques however is unnecessary to promote lower-social-cost electric service. This paper shows that existing cost-based planning tools when used within a multi-attribute framework are sufficient to identify lower-social-cost resource strategies and facilitate their selection under a competitive bidding process. By taking concerted action to separate the planning process into three distinct steps; strategy development, plan identification and plan implementation/resource acquisition, a planning and regulatory process aimed at providing least-social-cost electric service can be achieved.

INTRODUCTION

The reliance upon Integrated Resource Planning (IRP) techniques in power systems planning has increased tremendously over the past decade. First employed as a tool to facilitate “least-cost planning”—where numerous supply and demand-side and utility and non-utility resources required simultaneous evaluation—the role and scope of integrated resource planning has increased tremendously. IRP techniques are being called upon to address concurrent cost, reliability, and environmental issues—all against a background of increasing power sector competition and

uncertainty. This drive for increased competitiveness within the industry is manifesting itself in ways such as broader competitive bidding for electric power resources, and open access to bulk power transmission.

All these changes are being driven by a desire to see the electric service industry play the most productive role possible within the economy, for society, including the protection and preferably improvement of the environment. Competitive bidding is an extension of the least-cost planning doctrine developed to introduce market-type forces in the solicitation, evaluation, and selection of electric resources. Superimposed upon this is the desire to select those resources which will have the lowest emissions, and hence the lowest environmental impact. The diversity and flexibility of resource portfolios selected through the IRP process is also important, as we seek to manage the impacts of such diverse and shifting factors as fuel costs, electricity demand, and technological maturation and innovation.

To achieve these goals, IRP tools are increasingly being relied upon to identify not simply least-cost resource portfolios,¹ but least-social-cost portfolios that take into consideration all the issues society believes important. These changes have challenged planning professionals to develop and employ integrated resource planning techniques which deal effectively with the complexity of electric power resources and issues, the uncertainty of future demand and resource costs, and our less-than-complete knowledge of the impacts resource decisions will have upon ourselves, and our environment. The development and adaptation of integrated resource planning processes which identify and facilitate the implementation of least-social-cost electric services is the topic of this paper.

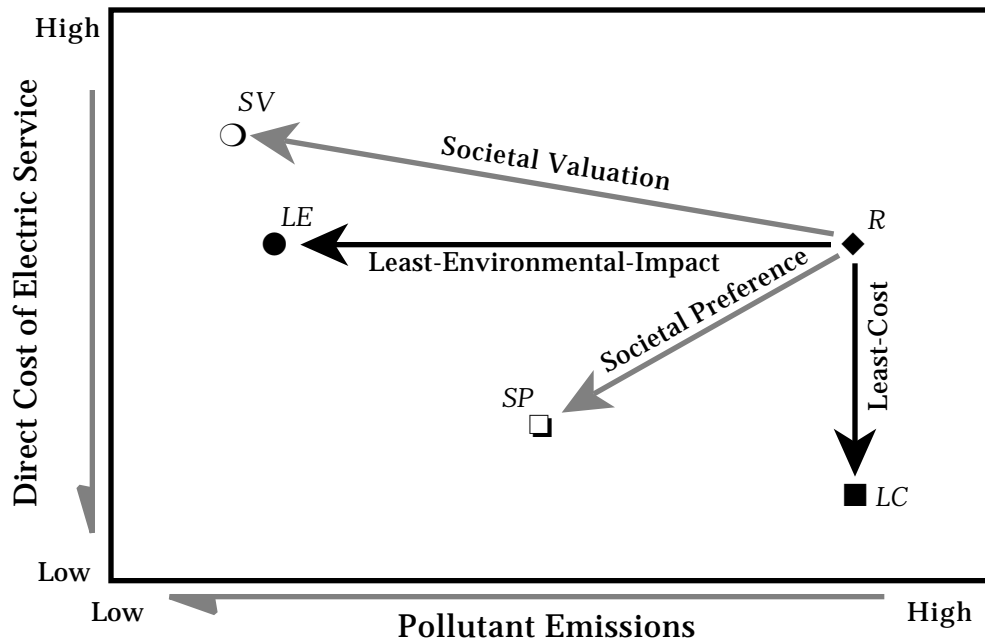
WHICH WAY TO LEAST-SOCIAL-COST?

To develop an IRP process that pushes the system towards least-social-cost, we must have an understanding of the direction in which least-social-cost lies. Figure One illustrates—in the broadest sense—how four integrated resource planning frameworks all reduce—to one degree or another—the social cost of electric service. The first two frameworks, “least-cost” and “least-environmental-impact” reflect the relatively straight-forward performance-based approaches of revenue, and emissions minimization. The other two frameworks reflect alternate decision

¹ Within this paper the term least-cost is synonymous with least-direct-cost, those costs born directly by consumer in the provision of electric service.

science approaches predicated upon first, societal valuation and second, societal preference.

Figure One: Performance Paths for Four Alternate IRP Frameworks



Starting from a reference point (R) describing initial system performance,² the least-cost framework seeks to minimize costs while holding emissions constant. Figure One illustrates the path system performance follows as resources are added to and removed from the system over time. With emissions along the x-axis, and direct costs along the y-axis, the least-cost IRP framework pushes system performance along a path heading straight down. Heading in a totally different direction is system performance under the least-environmental-impact framework. Here, where emissions are minimized while holding direct costs constant, strategy performance heads straight to the left.

If pollutant emissions only have deleterious net-environmental impacts, then both of these IRP frameworks reduce total social cost. The least-cost framework by reducing direct costs only, and the least-environmental-impact framework by

² For this discussion, the reference point refers to the initial direct costs and pollutant emissions of a given system. As resources are acquired, system performance moves away from this point based upon mix of resources the IRP framework favors.

reducing—by an unknown magnitude—the external costs associated with the health and environmental damages of residual pollutant emissions.

These two simple frameworks seek to minimize either direct costs or pollutant emissions, while holding the other attribute constant. Also shown in Figure One are two IRP performance paths that combine cost and emissions criteria. The “societal valuation” path reflects the cost and emissions impacts of an IRP framework based upon “society’s willingness-to-pay.” Within this framework increases in direct costs are allowed to achieve even greater emissions reductions than those obtainable with the least-environmental-impact framework. The rate at which direct cost increases are allowed to affect further emissions reductions is based upon the decision science concept of “utility maximization.” Within this analytic construct, society’s “utility function” reflects society’s environmental risk aversion, and consequent willingness-to-pay to avoid the unknown and unforeseen impacts of residual pollutant emissions. This framework also reduces the social cost of electric service, but only as long as society’s willingness-to-pay is equal to or lower than the environmental damage costs avoided.

The “societal preference” framework takes a distinctly different approach. While society may in fact be willing to increase revenue requirements to reduce emissions below the level required by environmental regulations, it would *prefer* to reduce revenue requirements *and* emissions. Figure One shows the societal preference performance path lying between the least-cost, and least-environmental-impact paths. Unlike the societal valuation framework, where the “adder” is defined as a positive cost increase to fund a given emissions reduction (+/-), societal preference is described as a ratio of cost to emissions reductions (-/-).³ In the language of decision science, this ratio describes the “objective function” with which to apply cost and emissions minimization/optimization tools.

Since we are always lowering costs and emissions under the societal preference framework, social costs are always reduced. However, since none of the four frameworks presume to know the health and environmental costs associated with residual pollutant emissions, we remain uncertain of which framework has us heading in the least-social-cost direction. Nor do we know which resulting mix of

³ Note that independent of the magnitude of the willingness-to-pay, or the preference to reduce costs relative to emissions, the valuation adder and the preference ratio are *always* of opposite sign.

resources (LC, LE, SV, or SP) has the lowest-social-cost, even though we know least-social-cost resides in the low cost-low emissions corner.

Notice that the ability to determine whether one strategy is of lower social cost than another is contingent upon our knowledge of the damage costs associated with residual emissions. As such, societal values and preferences employed in integrated resource planning are a reflection of how society treats the uncertainties associated with our incomplete knowledge of environmental and other impacts, as opposed to the knowledge of those impacts directly. As scientific knowledge increases, demonstrable health and environmental damage costs, arising from power system resource choice and operation, can be incorporated directly into cost-based resource planning tools. Direct costs are thereby transformed into “known costs,” while external costs remain “unknown costs;” uncertainties that must be dealt with via societal risk management and judgment tools.

STRATEGY DEVELOPMENT: KNOWLEDGE-BASED SOCIETAL ASSESSMENT

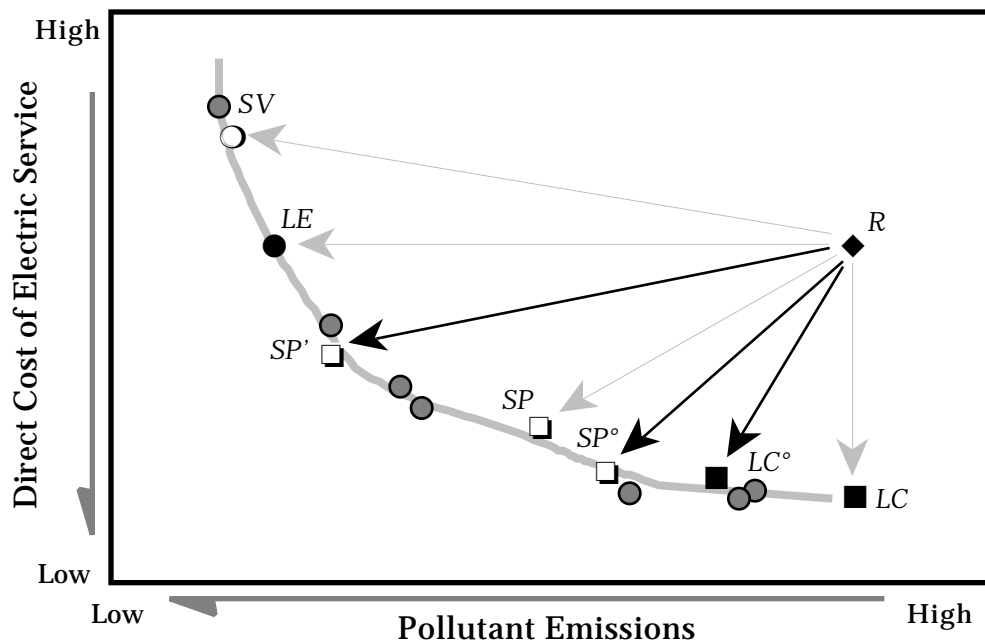
As the above discussion alludes, however far we progress—incorporating known environmental impact costs into resource evaluation—there will always be some degree of uncertainty. Since society’s level of omniscience, or clairvoyance, is unlikely to improve dramatically in the near future, how should the IRP process incorporate societal risk management into resource planning? Obviously, such decisions should be made with the best available information, and an understanding of the magnitude of the uncertainties involved. If knowledge is the command of facts, then wisdom is knowing the limits of one’s knowledge—and a wise and knowledgeable IRP process is one that will come closest to providing least-social-cost electric service.

To ensure that all the major issues, options and uncertainties have been considered in the integrated resource planning process, an initial educational, or brainstorm phase should be performed. This first basic step, called “Strategy Development,” involves industry stakeholders who identify important issues, uncertainties of major concern, and options that might be employed in achieving system performance goals. Existing cost-based planning tools are used within this broad context to identify those strategies which consistently perform well. The Analysis Group for Regional Electricity Alternatives (AGREA) at the M.I.T. Energy Laboratory has been actively working with a group New England electric industry stakeholders

to develop scenario-based multi-attribute analysis techniques that can be used to assess the performance of long-term strategies. The aim of this analysis is to come to a shared understanding of what a robust long-term strategy requires, so that successive plan identification and implementation steps can proceed in a more coordinated fashion.⁴

Strategy development essentially entails doing a broad-based set of analyses that scope out the “option space” of possible future system performance. Figure One showed a limited set of strategy performances based upon four pre-selected IRP frameworks.⁵ However, the scope of analysis at this juncture need not be constrained by these, or any other IRP decision frameworks. In fact, the strategy development phase is intended to assess as many combinations of resources as possible in order to develop the appropriate framework that implements the resource portfolio the regulatory community, with the advice of industry and community stakeholders, believes performs best. Figure Two illustrates the intent of this concept, by adapting and adding strategies to those discussed previously.

Figure Two: Mapping the Option Space of Possible System Performance



- 4 For an overview of the multi-attribute approach see the appendix. For more detailed discussions see Andrews (1992), and for use in open planning contexts, Andrews (1990), and AGREA (1991b).
- 5 PacifiCorps’s RAMPP-2 resource plan, recently submitted to the Oregon Department of Public Utilities, presents the performance characteristics of alternate strategies based upon various resource mixes combined and cost and value-based resource selection criteria (PacifiCorp 1992).

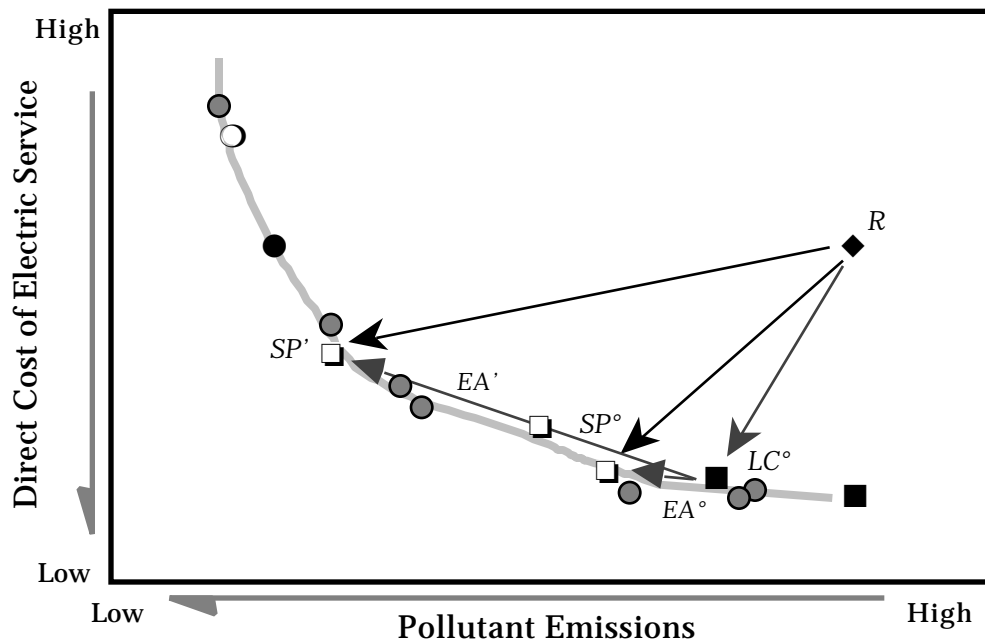
Figure Two assumes we have performed a broader range of analysis, unconstrained by pre-defined analytic frameworks. Shown are only those strategies for which there are no other resource combinations with lower costs *and* emissions. This population of strategies identifies a system performance frontier, often referred to as a tradeoff curve, for which the selection of one strategy over immediately identifies the cost and emissions tradeoffs of that decision. Development of these tradeoff curves serves two functions. First, all opportunities for concurrent cost and emissions reduction are identified. Independent of one's valuation of cost versus emissions, no strategy should ever be selected when there is another of lower cost and emissions. Second, it communicates the shape of the tradeoff curve, and therefore any opportunities for large emissions reductions at low cost, or points of diminishing return—beyond which the cost of emissions reduction becomes prohibitive. In actuality, such curves are difficult to specify precisely. This is due to the multitude of performance characteristics and uncertainties that are included in the simulation of an electric power system under a given strategy. However, today's computer technology has increased our ability to synthesize this information with a combination of graphical and statistical aids.

Close examination of the illustrative strategies in Figure Two begins with a more realistic representation of the least-cost strategy (LC), shifting it up and to the left (to LC°) as future environmental regulations take effect reducing emissions and impacting costs. One of the questions posed in the strategy development phase, and answered using scenario-based multi-attribute analysis is how much would it cost to reduce emissions below those levels required by environmental regulators. All strategies on the tradeoff curve to the left of LC° identify the most cost-effective resource portfolios (evaluated) to achieve a given level of emissions reduction. As shown in the figure, strategy SP° may reduce emissions at little or no additional cost. Depending upon the state of knowledge regarding the health and environmental impacts, the regulatory community may specify which strategy along the frontier should be pursued. Thus, SP', or even SV, may become the “preferred” long-term strategy. Within this context, the selection of SP' over LC° as a preferred long-term strategy is in effect an “explicit valuation” of society's willingness-to-pay for further emissions reductions, a decision made with the best available information.

Note that strategy development utilizing multi-attribute techniques serves to integrate the traditional least-cost planning framework with the societal valuation technique to develop an explicit societal preference. Figure Three demonstrates this.

Following a strict least-cost IRP framework through time would result in a system with performance characteristics LC° . Selection of SP° as the preferred strategy indicates a societal valuation, or “explicit adder” with a slope of magnitude EA° . Selection of strategy SP' indicates a willingness-to-pay EA' to further reduce emissions.⁶ However, these explicit adders only characterize a decision made based upon scientific uncertainty and the known cost impacts of choosing a specific strategy. The resources required to achieve SP' have already been identified, and may differ distinctly from those that push the system towards LC° or SP° . Knowing which resources are required to reach SP' sends signals to electric utilities, independent resource providers, and the regulatory community of the types of actions, resources, and incentives that will be required to achieve SP' . As will be discussed later, these signals can play a significant role in the development of independent and mature markets for supply and demand-side resources.

Figure Three: Integration of Least-Cost and Societal Valuation Methods through Multi-Attribute Tradeoff Analysis



Ultimately, the strategy development phase can only take us so far. No responsible industry concern is willing to commit today to ten or twenty years worth of resource decisions. Nor are they willing to codify a fuel, load or technological forecast,

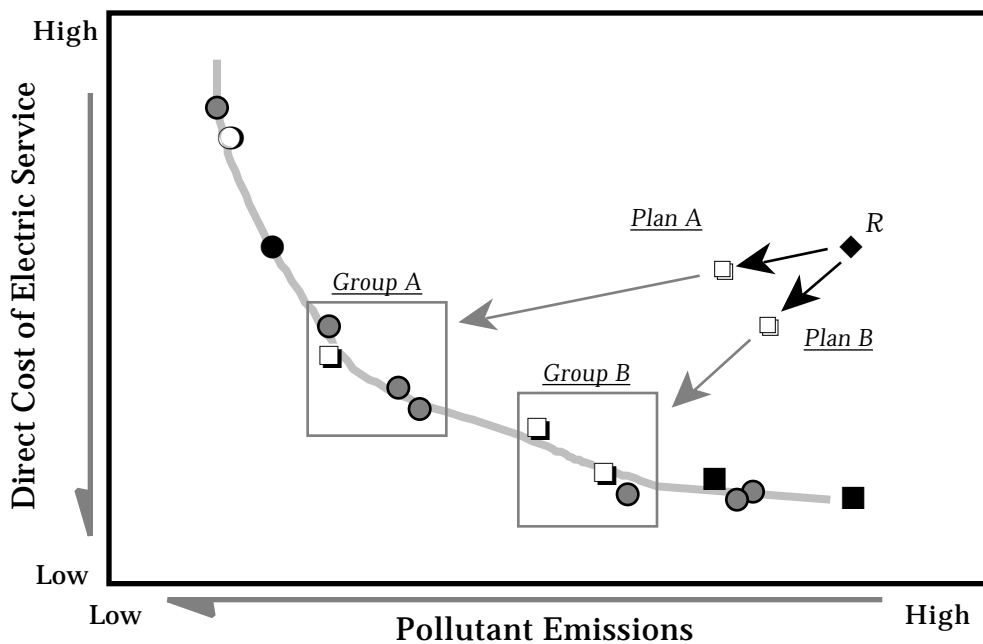
⁶ For a comparison of New England region cost-effective emission reduction rates, similar to EA° and EA' above, with the valuation-adder approach see Connors (1992).

thereby fixing strategy performances. Broad-based evaluations and strategy development is undertaken to ensure that no significant issues, uncertainties or options have been overlooked, and so that the resources selected in the short-term do not block avenues for future constructive action. Strategy development, therefore, lays the foundation from which a specific resource plans will be derived, and as such, is only the first step in the integrated resource planning process.

PLAN IDENTIFICATION: NEAR-TERM STRATEGY SPECIFICATION

Plan identification seeks to take the information developed in the strategy development phase, and decide upon a plan of action. While strategy development looks out ten or twenty years or longer, plan identification is concerned only with resource decisions that need to be made in the near-term. One novel aspect of moving from strategy development to plan identification is that the selection of a specific long-term strategy is not required. Figure Four illustrates this.

Figure Four: Using Strategy Development to Specify the Near-Term Plans
— Identifying Common First Steps



Given the uncertainty of forecasts, and our knowledge of environmental impacts and costs, only an area of the tradeoff curve need be identified as a target for long-range system performance. Common first steps, that eventually lead to any of a group of strategies, are those actions that should be included in the near-term plan.

Near-term resource acquisitions, identified as “Plan A” and “Plan B” in Figure Four, set the system on a path toward their respective targets on the tradeoff curve (the “Group A” and “Group B” strategies). Since strategy development recurs periodically, the tradeoff curve and preferred strategies are always being reassessed using the latest forecasts and available technological and scientific information. Since plan identification (and implementation) builds upon this re-identification of preferred strategies, near-term resource acquisition will remain coordinated with long-term goals.

Of course, resources that should also be identified in the plan are those necessary to meet near-term cost, reliability and environmental requirements. But the role of strategy development in plan identification does not stop there. Consider a set of strategies that identify a future need for infrastructure improvement in New England (Andrews and Connors 1992). Having identified a need to replace the region’s aging capacity with newer, more efficient, and cleaner technologies over the long-term, resource planners can be on the lookout for bargains when developing their plans. Counter-cyclical investments such as transmission and generation system enhancements—when the cost of capital is low—is another example of how strategy development can inform utilities and regulators of when it is opportune to make certain investments.

Other examples of how strategy development can assist in the development and acceptance of near-term plans arise in the desire to increase competitive bidding in resource selection, and anticipate future technological developments. If the preferred strategy identifies a long-term need for utility-sponsored conservation programs, then this signals lighting manufacturers and demand-side contractors of a multi-year need for their services, thus promoting a more mature and experienced market in demand-side management. An expressed need for new generating technology to replace aging capacity—independent of load growth—sends the same signal to prospective non-utility generators and power equipment manufacturers.

Plan identification, based upon a well integrated strategy development process, allows electric utilities to integrate their research and development efforts with the planning function as well. In areas where there has been rapid technological development, technology cost reductions, and institutional learning, the need to coordinate near-term plans with longer-term initiatives is essential. Modeling the impact of static or improving technological performance and costs informs decision-

makers whether specific program should be pursued aggressively or not, and whether actions taken today will block more effective efforts later.

Taking its cue from the resource decisions that describe the preferred strategy's performance, the plan identification phase derives minimum resource blocks for new demand and supply-side technologies, while identifying opportunities for existing infrastructure improvement, uncertainty mitigation, and technological advancement. Having identified these resource blocks, resource acquisition—as an extension of strategy development and plan identification can occur.

PLAN IMPLEMENTATION / RESOURCE ACQUISITION

As mentioned previously, a central feature of least-cost planning practice has been the institution of bidding processes in the evaluation and selection of actual resources. Up until this point most of the analysis in the IRP process could be performed with reasonably well defined “generic” resources. However, when it comes to actual resource procurement, evaluating resources by their proposed cost and performance characteristics is essential. These resource solicitations provide utilities with the exact cost and performance information required to undertake this endeavor.

Recent regulatory initiatives to increase competitive bidding within the integrated resource planning process may have actually gone too far. For example, Massachusetts's Integrated Resource Management (IRM) rules essentially preclude utilities from specifying resource blocks in their request for proposals (RFPs). This is done to enhance competition between supply and demand-side resources (Massachusetts 1990). In an effort to provide a level playing field to all resource providers, opportunities for coordinated resource portfolios—like those identified in the strategy development phase—may be overlooked. Too great an emphasis on the bidding process, and not enough on identifying long-term cost and emissions reduction strategies, runs the risk of reducing integrated resource planning into just competitive resource acquisition. Surprisingly, during the IRM rulemaking process, and with economic downturn in New England, demand-side management advocates as well as non-utility generators—who seek to increase their markets through the competitive bidding process—have recognized the need for the creation of “sheltered harbors” within the IRM process so that their respective markets can develop. When it comes to competitive bidding, the realization may be that it is

simply too much of a good thing. However, as discussed by AGREA (1991a), the four phase structure of the IRP process, developed by the Massachusetts Department of Public Utilities, lends itself well to the IRP approach presented here.

These issues offer a challenge to the electric utilities and regulators in how they should implement short-term resource plans. Clearly we want to maintain the features of competitive bidding, but not to the extent that we preclude implementation of what have been found to be cost-effective long-term strategies which reduce costs and emissions. As mentioned above, because we have not hard-wired our plan specification to a specific preferred strategy, there is greater flexibility in how to select resources during the plan implementation phase.

While the preferred strategy may identify some resource blocks for upgrading how we generate and consume electricity, the resource plan need not have these blocks define one hundred percent of the short-term resource need. Say short-term resource requirements identify a need to select 500 MW of equivalent supply and demand resources to meet reliability criteria, with an optional 200 MW in additional infrastructure enhancements. In order to be consistent with the preferred set of tradeoff curve strategies a minimum 250 MWs should be acquired as demand-side resources and 150 MW as supply-side. This provides a minimum of 100 MWs to fill via inter-resource competition, with as much as 300 MWs being selected, depending upon the type and cost characteristics of proposed resources.

An analogy to the three phase IRP process of strategy development, plan identification and resource acquisition is grocery shopping (yes–grocery shopping). Strategy development is analogous to determining what you need to have a balanced diet. Plan identification is like checking the pantry and fridge, and making a list of what’s needed to get through the week, and what you might want to stock up on. Resource acquisition is akin to checking supermarket circulars, and purchasing what you want, from who you want, depending on what you need, what’s in season, and what’s on sale.

CONCLUSIONS

Integrated resource planning is undergoing continual changes as it is relied upon to identify and select not only least-direct-cost portfolios of options, but those that simultaneously incorporate the uncertainties and risks associated with the “external” costs of residual pollutant emissions. Of the techniques most relied upon

to promote least-social-cost electric service through the IRP process have been societal valuation methods, often based upon past regulatory decisions and resulting costs, as a reflection or “implicit valuation” of society’s willingness-to-pay.

Since our knowledge of the health and environmental impacts from these emissions remains quite incomplete, the inclusion of societal factors in the planning process is more of a technique to mitigate the risk of those unknown impacts, than it is to incorporate those impacts directly. Through a three phase IRP process which first identifies the long-term opportunities for concurrent direct-cost and emissions reduction, and the most cost-effective means to achieve further emissions reductions, a better informed process to deal with these environmental uncertainties can be achieved.

The three phases of the integrated resource management process discussed here include strategy development, plan identification and plan implementation/ resource acquisition. Strategy development entails broad-based planning studies that explore the performance of strategies over the range of issues, uncertainties, and options industry leaders and stakeholders believe important. Identification of the performance frontiers and tradeoffs associated with various resource decisions works to reduce costs and emissions as much as possible, and identify where opportunities for additional emissions reductions, at modest cost, lie. Identification of a preferred strategy, or set of strategies, is then an “explicit valuation” of society’s willingness-to-pay to reduce environmental risks. Existing cost-based planning tools are capable of identifying these opportunities, if employed in an analytic framework such as scenario-based multi-attribute tradeoff analysis.

The plan identification step seeks to identify and specify the initial first steps of the preferred strategy(ies). With this knowledge, existing competitive bidding processes can be adapted to acquire resources which meet short term resource needs, while holding to the long-term strategy, appraised of opportunities and contingencies that might arise as events differ from anticipated trends. In conjunction, these three steps, employing using the best available information, can lead to more coordinated resource selections that continually promote least-social-cost electric service.

ACKNOWLEDGMENTS

This piece benefits from the active participation of those electric utilities, regulators, and consumer and environmental interest groups involved in M.I.T.'s New England AREA Project. Since 1988, their comments, concerns, and support have helped AGREA members develop broad-based planning techniques, and apply them to identify opportunities for electric sector improvement. The contents of this paper however, reflect only the views of the author, and should not be interpreted as positions held by any project participants. The financial support of utilities participating in the New England AREA Project, and the technical support of NEPLAN and its staff is gratefully acknowledged.

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INTRODUCTION

Since 1988, the M.I.T. Energy Laboratory's ANALYSIS GROUP FOR REGIONAL ELECTRICITY ALTERNATIVES (AGREA) has been developing and using multi-attribute analysis techniques. The general technique, briefly described below, was developed to facilitate analysis of issues characterized by a high degree of controversy, uncertainty and complexity.

The Scenario-Based Multi-Attribute Tradeoff Analysis technique recognizes the complexity, and uncertainty associated with the analysis of any given system. It also recognizes that the performance criteria associated with the evaluation of various options cannot be reduced to a single, or even several, units of measurement (referred to as attributes). Furthermore, the interpretation, and evaluation of multiple attributes may differ markedly from individual to individual, thereby voiding the use of many traditional decision analysis techniques which require the definition of an "objective function" with which to collapse attributes for use in optimization routines.

WHAT IS THE SCENARIO-BASED MULTI-ATTRIBUTE TRADEOFF APPROACH?

As Figure A-1 indicates, Scenario-Based Multi-Attribute Tradeoff Analysis (commonly referred to as simply "tradeoff analysis") begins with the identification of the important issues, and developing a set of attributes with which to measure performance relative to those issues (1). The number of attributes described is limited only by the collective interests and concerns of the research's intended audience and the ability to perform the attributes' calculation.

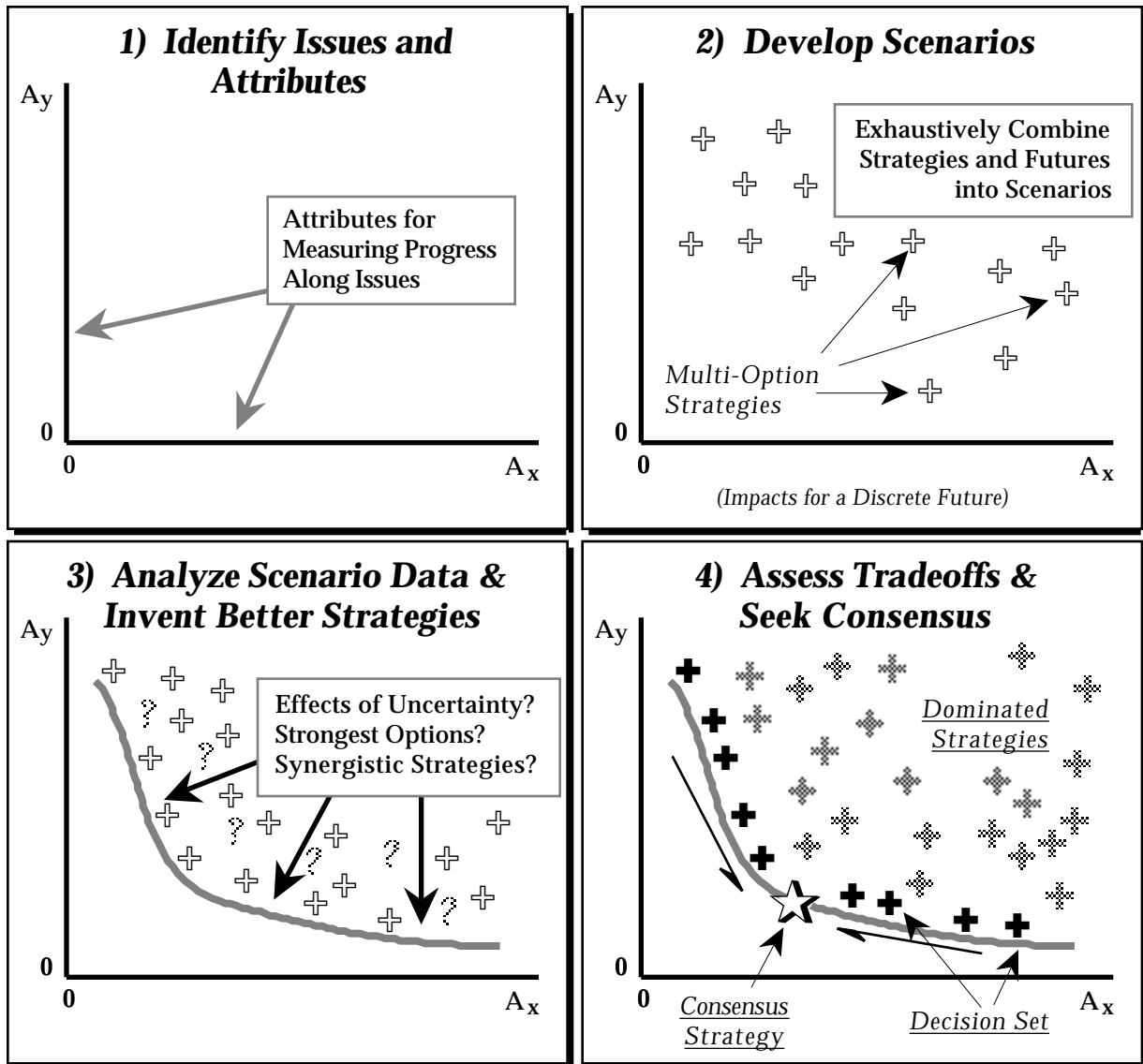
Concurrent with the description of issues and their attributes, multi-option strategies, and related uncertainties are identified. Each strategy is evaluated across a range of uncertainties to yield a set of scenarios. The multiplicative effect of combining multiple strategies and uncertainties commonly yields a large number of scenarios (2).

Scenario analysis is performed by the simulation of a given system, following each strategy, and for the combination of uncertainties identified (called "futures"). The scenario analysis yields an attribute database with which strategies can be evaluated and compared. At this point better combinations of options may be identified, or various attributes and uncertainties may be added or dropped from the analysis (3). Additional scenario analysis may then be performed, until the range of strategies evaluated constitutes a set of for which significant improvements are either unlikely, or difficult to analyze.

Once this stage is reached, nearly all of the important impacts associated with the choice of a strategy have been identified. The risks associated with a strategy's choice, in addition to its performance (for a given set of circumstances) have also been quantified. At this point, the analysis's audience, preferably stakeholders and

decision-makers from industry, can identify a preferred strategy, or class of strategies, from the population of decision set strategies lying along the tradeoff frontiers (4). Fine tuning of that strategy can then commence.

Figure A-1: The Four Basic Steps to Performing Scenario-Based Multi-Attribute Tradeoff Analysis



ADVANTAGES OF SCENARIO-BASED MULTI-ATTRIBUTE TRADEOFF ANALYSIS

Tradeoff analysis has several advantages when it comes to providing quantitative information in a joint fact-finding environment. Since it begins with an identification of important issues, it automatically addresses the range of concerns held by the advisory group, or audience, for whom the work is being done. The *a priori* identification of issues and attributes also serves to divorce discussions of

acceptable performance criteria from the technological composition of a given strategy. This is important for politically charged areas of analysis since, in such forums, many participants enter the discussions with firmly-held opinions, often comprised of an idealized technology which represents the “correct answer.”

Broad-based selection of uncertainties, as well as the choice of technological and other components for multi-option strategies, have a similar effect. This wide selection of scenario components side-steps areas of contention by including all the technological options and uncertainties of greatest importance to an advisory group, thus ensuring that each participant’s interests are reflected in the analysis. This technique also helps to make the results more credible to a broader, often adversarial, audience.

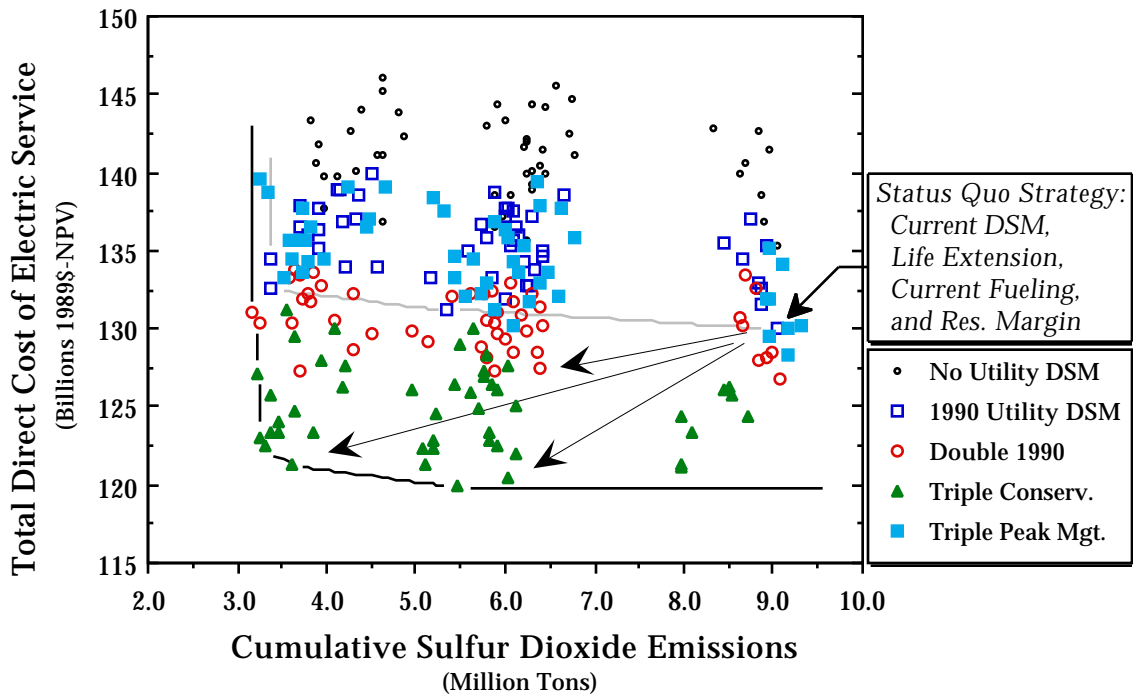
Assessing the performance of a broad range of scenarios, for literally hundreds of attributes, is an achievable analytic task with today’s computing technology. An emphasis on computer analysis utilizing system simulation, or bottom-up analysis is preferable to techniques rooted in econometric, correlation, or top-down approaches. This is simply because the scientific foundation of thermodynamics, fluid dynamics, and even cost accounting attracts less controversy than models that hinge on such assumptions as inter-sectoral labor mobility, or the actions of “rational man,” for example. Physical system models also provide greater specificity when the details of one strategy’s behavior warrant closer examination.

Finally, tradeoff analysis can be used to easily communicate general trends in system behavior, particularly when using computer-assisted graphing tools. These tools have been used effectively to communicate the cost and emissions reduction opportunities available to the New England electric power sector for audiences that have no technical background in either electric power system operations or planning. Figure A-2 provides an example of how scenario-based multi-attribute tradeoff analysis can be used to convey such information.

Figure A-2 illustrates that there are numerous strategies that have lower costs (in Billions of dollars) and emissions (in millions of tons, SO₂), than a political path-of-least-resistance strategy. Strategies that are more effective at achieving cost and emissions reductions are easily identified using tradeoff analysis.

Dynamically changing the attributes along each axis, and the future for which these strategies’ performance pertains, allows the analysts to rapidly identify and explain which strategies consistently perform well across a broad range of issues. These computer-assisted graphical manipulations are easily performed with the use of commercially available statistics and database software.

Figure A-2: Communicating the Cost and Sulfur Dioxide Emissions Performance of Multiple Strategies



(Source: AGREA 1991 Scenario Set)

AGREA staff have used such techniques effectively to convey the large opportunities for concurrent cost *and* emissions reductions available to New England. The use of scenario-based multi-attribute tradeoff analysis, in conjunction with computer-assisted presentation techniques, has enabled the group to communicate vast quantities of complex and detailed information to representatives from state and federal regulatory agencies, business and industry, and environmental groups, as well as people in the electric service and academic communities. Demonstrating that these reductions can be achieved through the coordination of end-use *and* supply-side efficiency improvements, when the regulatory debate is focused upon resource excluding, competitive bidding processes, is assisting the region's development of better long-range strategies.

Since scenario-based, multi-attribute tradeoff techniques apply more to the general research approach, rather than the details of specific analyses, the technique can be easily transferred to other areas of scientific endeavor.