IMPROVING THE ANALYTICS OF OPEN PLANNING PROCESSES: Scenario-based Multiple Attribute Tradeoff Analysis for Regional Electric Power Planning

by

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Abstract

Controversy and uncertainty may mandate the use of negotiation, collaboration, or other approaches that open up the planning process. Participatory planning situations that involve complex technical questions are likely to need sophisticated analysis tools to support the decision making effort. This research contributes to the development of a technique designed to serve the analytic needs of consensus-building processes in this context of complexity, controversy and uncertainty.

Scenario-based multi-attribute tradeoff analysis is a technique that allows negotiating parties to observe the performance of strategies, the effects of uncertainty, and the interactions among components of a complex system in multi-attribute space. This helps the group to invent better strategies having more of the characteristics that each party prefers, thus improving the potential for consensus. By involving the parties in the analysis, their creativity is harnessed, a shared understanding of both issues and options grows, and the results are more likely to be accepted by the group. The analyst plays a non-traditional role in facilitating the joint fact-finding effort among the parties.

The efficacy of this approach was tested on two major electric power planning projects in New England, one involving an expert group and the other non-expert groups. The participants in each project defined issues and attributes, developed scenarios, explored system behavior, and articulated preferences regarding difficult tradeoffs. Each step of the approach was thus tested in practice, allowing the formulation of a revised framework incorporating what was learned.

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1. INTRODUCTION

Technical complexity confounds our efforts, as a society, to deal successfully with many of today's planning challenges. Some policy makers (and their constituents) lack an adequate comprehension of the ever-more-important *black box* of technology as it applies to their policy priorities. Likewise, the technologists involved in the design of projects, products, and processes may fail to understand their social, economic, and political context. We need to develop more effective ways of reaching sound, democratic decisions on technology-dominated issues. In order to do this we need to learn better how to plan in ways that acknowledge technical complexity, controversy and uncertainty. I contribute to our ability to do so with this research .

In this chapter I will briefly define the motivating problem, provide an illustrative example, and outline the remainder of the dissertation.

Problem Statement

Certain types of planning efforts develop paralysis along the route to completion. These often involve large, technically complex components with wide-ranging economic, environmental, and other impacts. They appear to be vulnerable to delays at many points along the path from planning, to approval and final implementation. The delays are more often due to interventions by outside parties than to practical implementation problems.

The broad goal of a planning effort may be widely perceived as important, and even laudable, yet outside parties may still attempt to block specific projects that are proposed. They do so because they don't believe that the specific projects represent the best possible way to achieve the broad goal of the planning effort – in equity or efficiency terms – from their points of view. Projects with larger impacts are, of course, likely to generate fiercer interventions. If every specific project is opposed, then the overall planning process may grind to a halt, leading to an outcome that no one wants.

What are the conditions that breed this planning paralysis, and how may it be overcome? This pair of questions has provided the general motivation for this research. An example will help to flesh out the problem.

A New England Example

The 1980s were marked by a dramatically decreasing reserve margin between the supply and demand for electric power in New England, leading to crises during peak demand periods – such as hot summer days and cold winter nights (see Figure 1-1). However, stakeholders in the regional electricity debate differed widely on the choices which should be made to mitigate these problems. There was strong polarization over what was the correct technological path to be followed, with environmentalists advocating conservation, regulators encouraging independent power production, and utilities relying on foreign power purchases in lieu of financially-risky traditional power plant investments. In the mid-1980s this led to a state of paralysis, during which it seemed that no positive action was being taken in any direction. By 1988, the situation deteriorated to the point that the regional power pool had to invoke emergency operating procedures such as voltage reductions more than thirty times – breaking all previous annual records.

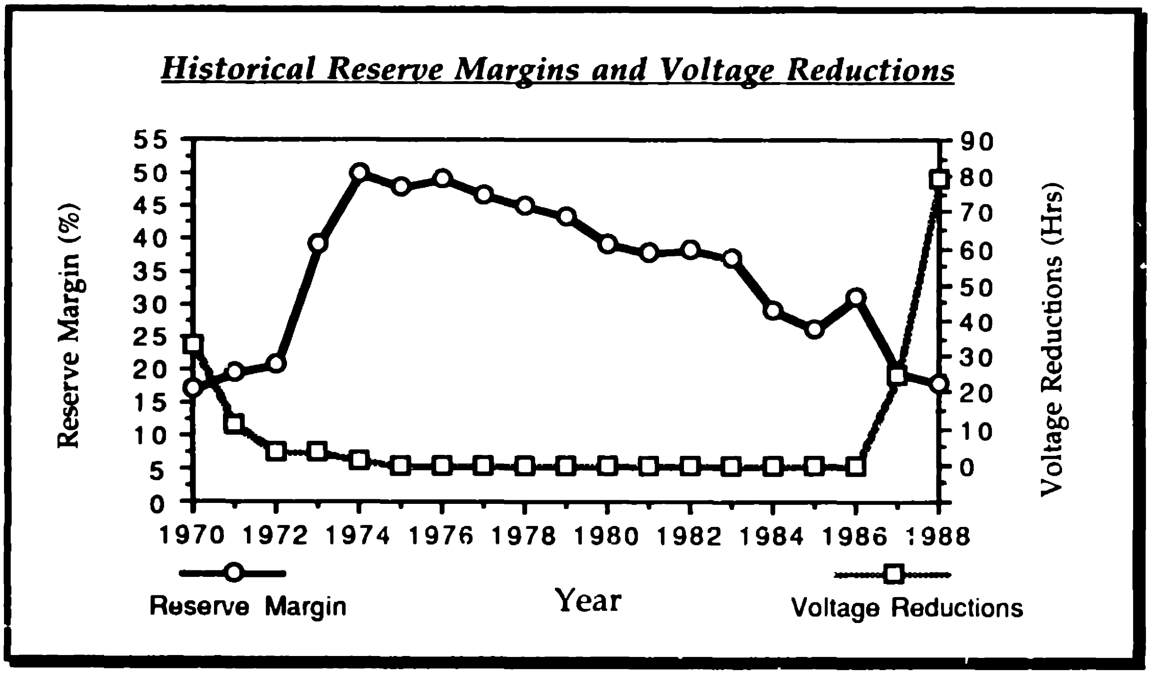

Figure 1-1: Historical Reserve Margins and
Emergency Voltage Reductions in New England
Source: Andrews et al, 1990, based on NEPOOL data

This situation did not develop overnight. Icons such as the Seabrook nuclear power plant and the Hydro-Quebec transmission lines littered the political landscape of the region, demonstrating a long history of disagreements about the "right" way to ensure adequate electric service. The story of Seabrook sketches out the conditions leading to policy paralysis.[1] This ill-fated project was conceived of in the boardroom of Public Service of New Hampshire in about 1970, during a period when utilities all over the world were still riding the nuclear bandwagon. Its need was not questioned by New Hampshire state regulators in 1972 – sustained rapid load growth had been the norm for the previous twenty years, and everyone expected this trend to continue. The down-side of nuclear technology had not yet revealed

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[1] The following is based on a chronology in the Boston Globe (1990).

itself to public view, and the newly-passed Clean Air Act suggested that non-fossil generation technologies were the way to avoid regulatory tie-ups.

The public did not really realize that the plant was going to be built until the utility began construction in 1976. The suddenly-revealed decision to site the plant adjacent to a beautiful wetlands area, near one of the most popular beaches in New England, galled many environmentalists who felt that too much of the region's coastline had already been lost to development, and that thermal discharges would kill nearby marine life. Increased concern about nuclear waste disposal and catastrophic risks heightened public opposition to the plant. A variety of outside parties felt that the utility had exercised poor judgement in both the site and technology choice. The unilateral decision taken by the utility began to be second-guessed by other parties.

The oil price shocks of the 1970s, while making non-fossil options attractive, also reduced electricity demand and diminished the justification for this new capacity. The economic downturn in the region during this period further dampened demand. The 1979 incident at Three Mile Island galvanized public opposition to nuclear technology, and spurred the imposition of new standards for plant construction, forcing revisions to many parts of the half-finished plant. Unable to get the satisfaction of direct negotiations with the utility, Seabrook opponents learned how to use the regulatory process and the court system to delay progress on the plant, while high real interest rates dramatically compounded the cost of each new delay.

Public Service of New Hampshire appeared to believe that the best way to overcome opposition was with momentum. Rather than acknowledge that conditions had changed, and that the option that had seemed so attractive under 1970 assumptions now looked less appealing, to several stakeholders at least, it ploughed ahead with the full project, two units totalling 1150 x 2 = 2300 MW of capacity. It kept investing in the project in the belief that, when presented with a *fait accompli,* the public would accept it. This proved to be an extremely costly tactic, because when Seabrook II was about 25% done, this second unit had to be mothballed, and an investment of hundreds of millions of dollars could not be recovered. Further, the legal challenges to bringing the first unit of the plant on line succeeded in causing years of delays, during which the plant sat idle and unproductive, and capital costs soared. The final cost of the plant was approximately 6.35 billion dollars, of which only a fraction could be recovered from electric ratepayers. These losses ultimately bankrupted Public Service of New Hampshire and caused severe financial problems for other co-investors.

It took some twenty years for Seabrook to progress from planning to startup, at a final cost that no one would have been willing to pay had they known what it was in advance. This outcome was partly a function of a flawed planning and implementation process that did not seek a planning consensus among all interested parties, yet allowed outside parties to intervene in later stages of project implementation. It was exacerbated by a regulatory structure and legal dispute resolution mechanism that inspired extreme positions and brinksmanship, leading to win-lose outcomes instead of a search for mutually productive middle ground. Finally, the option chosen by this process lost much of its attractiveness when external conditions changed; it lacked the flexibility to adapt and the robustness to thrive in an uncertain world.

Similar problems plagued many aspects of New England's electric power debate during the 1980s. In Massachusetts, for example, not a single power plant proposal survived the siting process, from the creation of its

Energy Facilities Siting Council in 1976 until the end of 1987, due in part to successful interventions by environmental and consumer interests (MA EFSC, 1990). Yet conservation, the option favored by environmentalists, was largely ignored by the utilities. No one got their favorite option, and everyone was unhappy with the reliability problems resulting from this deadlock. More complex strategies, consisting of packages of diverse options, were simply not explored in the public debate, even though they represented a way out of this dilemma.

One can think of similar stories in the areas of electric power planning, water system design, and transportation planning. Related problems are likely to exist in realms as diverse as global climate change policy responses and river basin management. Paralysis during the process of planning or implementation indicates that, somehow, a needed consensus was not obtained.

These project proposals are often developed by one party on their own, and presented full-grown to an unsuspecting public. Parties affected by the decision then must formally intervene in order to have input into the project design. Since they are not involved in the earlier stages of the planning process, in determining the need for a particular facility, and exploring the wide menu of options available for meeting that need, they often do not believe that the particular proposal put forth is the right one. Also, since the project proposal does not benefit from each stakeholder's input, it is quite likely that it is not the "right" choice from every stakeholder's point of view. If the only leverage a stakeholder has is to delay or halt the project in court, then she will attempt to do so. If the only input a party has is a yes-or-no vote on a single option, then public debate is inevitably simplistic, pitting alternative options against one another instead of coordinating them into a balanced strategy. As long as the only input outside parties have into the planning process is their litigated veto, then paralysis of the process is a likely result.

What is needed, obviously, is a process that seeks a consensus when a consensus is needed. If outside parties hold some veto power, then they should be consulted, and their views accommodated in the planning effort, so that the veto is less likely to be exercised. These parties need to be convinced that the options have been thoroughly explored, and that whatever specific strategy is ultimately proposed is the best available. The earlier this is done in the planning process, the easier it will be to adjust the components of the plan.

A Look Ahead

The body of this dissertation begins, in Chapter Two, with a discussion of three potential barriers to consensus: controversy, uncertainty, and complexity. In traditional planning and project implementation processes these factors may be pre-conditions for planning paralysis. Each of the three barriers is discussed, first in general terms, and then in the context of the applied focus of this research: electric power planning. In Chapter Three I offer a general approach for overcoming these barriers to consensus, by opening up the planning process while ensuring expert input. An important part of this approach is the use of a scenario-based multi-attribute tradeoff analysis framework, which is outlined in Chapter Four.

Next, I turn to the applied portion of the research, introducing in Chapter Five an open planning experiment, at the regional level, for New England's electric utilities. Chapter Six continues the story of the New England project, focusing on the exploration of system behavior. Chapter

Seven concludes the discussion of the New England project, emphasizing the understanding of stakeholders' preferences. Chapter Eight examines a contrasting application of the approach involving non-expert participants, in the Commonwealth Electric Open Planning project. In the final chapter I summarize conclusions about the efficacy of the approach as revealed by the results of the New England and Commonwealth Electric projects, plus lessons about the analytics of open planning generalizable to other contexts, and recommendations for further research.

2. BARRIERS TO SUCCESS: CONTROVERSY, UNCERTAINTY AND COMPLEXITY

Paralysis can result when planning processes that depend on some level of consensus fail to achieve it. Yet consensus is often quite difficult to get. It depends upon finding innovative solutions to difficult planning problems, and doing so in a credible manner. Adversarial processes for the planning, approval, and implementation of large projects, plus massive uncertainty and technical complexity, are barriers that often deter our inventiveness. They combine to throttle constructive debate on many important planning issues. I look each of these three factors in this chapter, and explore their effects on planning in the electric power context.

The Value of Consensus

Consensus is a worthy goal of planning processes for a number of reasons. Both contractual and utilitarian arguments can be made to reinforce the intuitive, common-sense justifications for this goal.

Taking the moral high ground, philosophers such as Rawls (1971) have encouraged society's actors to make decisions as if there were a social contract binding us. If we imagine ourselves as rational actors in the "Original Position" before the development of society, we know that we will live in a society but we cannot be sure of our status in that society or of the distribution of natural talents. Therefore it is in everyone's interest to guarantee liberty and equal opportunity to all, and to approach major decisions using the maximin principle, maximizing the position of the worst-off segment of society (Grey, 1976). In other words, we should act in a way that recognizes that if we were in the weaker position or in the minority, then we would want the stronger parties to acknowledge our needs. A consensus-seeking planning process would do this.

Utilitarian arguments for consensus are also quite credible. As we saw in the Seabrook case, a democratic society imposes checks and balances on activities to ensure that all points of view will eventually be heard. If a developer unilaterally proceeds with a project that is detrimental to other parties' interests, then the opponents can go to court to try and stop the project or recover damages. On capital-intensive projects especially, the delays caused by legal challenges may reduce the attractiveness of the project to its developer. The ability to delay progress gives outside parties some measure of veto power over project proposals – overriding this veto may entail significant costs. Therefore, enlightened self-interest suggests that there may be utility in diminishing the possibility of vetoes by seeking a consensus on the planning proposal.

The utilitarian argument may also be framed in terms of risk management. Developers who want to assure stability in the decision making and approval processes, rather than subjecting their projects to flip-flopping outcomes on appeal and counter-appeal, might seek wide approval for their plans (Susskind & Cruikshank, 1987, p. 32). Risk-averse developers may want to buy insurance against the loss of sunk investments by getting a consensus on the project details before implementation begins.

Whether the motivation is enlightened self-interest or an egalitarian sense of justice, consensus seems to be a desirable goal of planning processes. However, it is no easy task. Achieving consensus depends on the process used, the people involved, the problem at hand, and their success at finding innovative solutions.

The Need for Creativity

Creativity is a widely acknowledged – but rarely emphasized – quality of planning efforts that can let us find better ways to achieve our stated goals. It can help to increase the efficiency with which we, as a society, use resources to meet our economic needs. It may also allow us to expand the range of social goals that may be accommodated. Without it, planning remains a zero-sum game where stakeholders bicker about how to slice up a fixed-size pie (Fisher & Ury, 1981).

In consensus-seeking planning processes, this inventiveness is absolutely crucial. Zero-sum games by definition have winners and losers. No party will agree to an outcome that leaves them worse off than they were before, making consensus unlikely unless the pie can be expanded to ensure bigger pieces for everyone at the table. How can we turn the planning effort into a positive-sum game? How can we ensure that the creativity of the stakeholders is harnessed? We need to identify the barriers to success and then overcome them.

Controversy Can Stifle Creativity

Controversy is one factor that can stifle creativity when it occurs in the context of our litigious society, where a planning decision made by one party is often later contested, with the ultimate judgement on the project's merits being made in a courtroom or hearing chamber. Adversarial interactions and their associated win-lose outcomes encourage the use of information as a weapon rather than as a tool, and cause parties to posture from extreme positions rather than look for mutually beneficial middle ground (Susskind & Cruikshank, 1987). Controversy itself can be healthy, and ardent debate can uncover important information. However, if that information comes too late in the planning process to spur our inventiveness, as is often the case when a project is legally contested, then it has less value. That information needs to come out much earlier in the planning process.

Electric Power Planning Is Full of Controversy

As was mentioned in Chapter One, in New England during the 1980s, various parties in the electric power debate carved out extreme positions – conservation-only versus nuclear-only, for example – which led to policy paralysis and no activity of any type to ensure the future adequacy of electric service. The electric power industry as a whole is embroiled in a variety of controversies, as described below.

Electric power systems are comprised of numerous big, long-lived, high-impact, quasi-public investments. These are highly visible to the public, and affect a wide variety of parties: customers, shareholders, environmentalists, business and industry, neighborhood groups, government regulators, and others. These many stakeholders have divergent points of view on specific issues.

Over the past 75 years, electricity has transformed itself from a specialized industrial energy source into a necessity used by all segments of the population (Barkenbus, 1987). A recurring controversy is whether to consider this commodity a privately provided public good or a regulated private good.

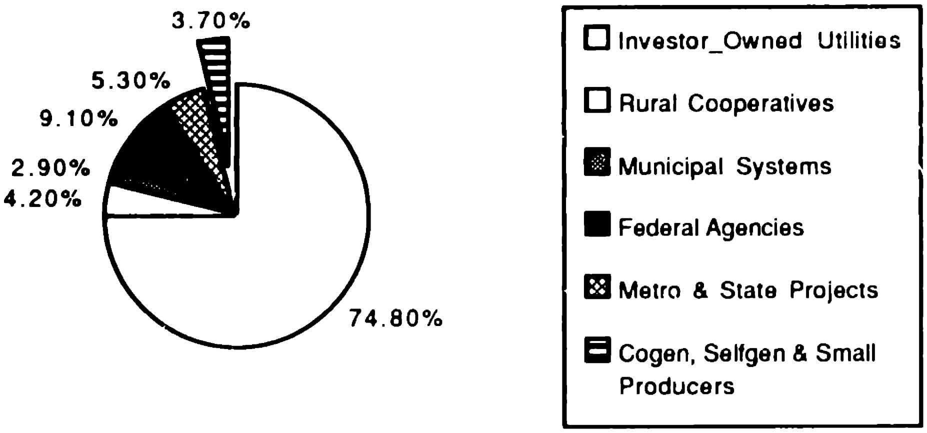
During the last decade, in particular, there has been an increasing dependence of all customer classes on high quality and reliable electricity supplies, due in part to the proliferation of microprocessors in household, commercial, and industrial appliances and equipment (Andersson & Taylor, 1986). The franchise agreements of the regulated utilities require them to serve all current and expected demands within their service territories, at acceptable quality levels. However, as the customers' quality needs have become a moving target, the socially optimal level of reliability towards which the utilities should aim has become controversial.

Over the last 30 years, public concern over environmental impacts has dramatically mounted. Many localities are unwilling to accept large, new power plants sited within or near their borders. Nor are they willing to allow local disposal of the wastes, whether ash or spent nuclear fuel, produced by these plants. Further, there is heightened sensitivity to both the air and water pollution impacts of electric power production. Controversy erupts over determinations of which environmental impacts are acceptable and which are not.

Over the past 15 years, electric price volatility also has concerned many customers. Several factors affected this: (1) the oil shocks, showing the industry's vulnerability to fuel price fluctuations; (2) high real interest rates, showing its vulnerability to capital cost fluctuations; (3) imprudent utility investments, either in unneeded or unsafe plants; (4) incompetent construction management, leading to cost overruns; and (5) regulatory inconsistency, fanned by inter-agency conflicts, leading to additional total costs, and large sporadic rate increases. Both the average level and variability of electricity prices have become a matter of controversy.

The natural monopoly features of electric power systems include significant economies of scale in generation and transmission, and territorial monopolies in the distribution of electricity. In the United States, these characteristics have led them to be structured either as investor-owned, regulated local monopoly franchises, or as publicly-owned entities (see Figure 2-1). As such, there is a tradition of detailed governmental oversight of utility pricing, and more recently, as a result of the factors mentioned above, their operations and investments have also come under close regulatory scrutiny. This tension between the regulators and the regulated also breeds controversy.

Figure 2-1: Electricity Generation in the USA by Ownership (1985)
Source: Based on Smith 1988



The state regulatory agency with oversight (DPU, PUC, or PSC) plays a primary regulatory role for investor-owned electric utilities, by approving tariff structures, setting allowed rates of return on investments, and determining which investments can be included in the rate base. However, a number of other federal and state agencies also perform regulatory functions affecting utility decision making. Each provides opportunities for interventions in the planning process.

At the federal level, the Federal Energy Regulatory Commission (FERC) monitors interstate bulk power transactions and fuel transport, and enforces the Public Utility Regulatory Policies Act (PURPA), which requires utilities to purchase electricity from independent power producers. The federal Environmental Protection Agency (EPA) sets air and water pollution standards, and assists the states in monitoring pollution impacts and enforcing the standards. The federal Department of Energy (DOE) monitors special laws, such as the 1978 Fuel Use Act (recently repealed), which constrain utility planning and operating decisions. At the state level, siting councils or environmental management agencies pass judgement on power plant and transmission line siting proposals. A variety of other agencies monitor other issues, such as public health and safety, occupational hazards, and emergency planning. These agencies render controversial decisions and provide pressure points for outside interveners to make their opinions felt.

The electric power planning process is full of controversy of many types, and involves a wide variety of stakeholders. The commodity and its production process affect many people.

Uncertainty Can Hinder Constructive Debate

Uncertainty can also hinder constructive debate. It increases the perceived risks of making decisions about long-lived investments, exposing decision makers to second-guessing by other concerned parties (Lough & White, 1988). It also makes discussions about the merits of planning options more diffuse, because parties expect the future to unfold in different ways. Since perceptions of risk vary dramatically from one individual to another, parties interpret the significance of uncertainty differently (Slovic et al, 1979).

Planning in the context of a complex system involves the uncertainties of system behavior in addition to those imposed by exogenous factors. Both types of uncertainty make planning more difficult.

Electric Power Planning Is Full of Uncertainty

Expectations for economic growth, fuel prices, capital costs, and technology availability are among the uncertainties in New England's electric power debate. Differing expectations for future growth in electricity demand have been a fundamental part of the controversy over the need for new electric power investments in the region.

Most North American utilities have seen these uncertainties increase during the past twenty years. Once the pattern of rapid, sustained load growth was broken by market saturation and the oil shocks of the 1970s, many utilities found that monotonic forecasts were more often off than on the mark. Southern California Edison, for example, took a retrospective look at its forecasts, planned additions and actual new capacity installations over the twenty year period between 1965 and 1985. They found that "out of a total 34,000 megawatts of planned resource additions, only 9,000 megawatts were actually built" (SoCal Edison, 1988). Different types of surprises in each planning period rendered their previous assumptions inappropriate – the Northeast blackout of 1965, the Alaskan oil discovery of 1968, Earth Day in 1970, the Arab oil embargo in 1973, the West coast drought in 1976-77, the National Energy Act (PURPA, Fuel Use) in 1978, Three Mile Island and the Iranian crisis in 1979, and so on until the present day.

Electric power systems are complex, and the individual components such as power plant operations and customer demand behave stochastically. Many of these factors can only be represented probabilistically, making uncertainty an inherent part of any analysis of system behavior.

These systems are also sensitive to many exogenous factors, many of which have shown increasing volatility over time – fuel prices, load growth, lead times for permitting and construction, and capital costs especially.

However, different parties perceive the risks associated with these uncertainties differently from one another. For example, utilities are more concerned with capital recovery risks, while members of the public may be more concerned with nuclear power plant performance-related safety hazards.

All of the uncertainties described here hinder constructive debate about electric power planning options. This makes consensus a difficult goal to achieve.

Complexity Confounds Creativity

Complexity can confound efforts to think creatively, because not all planning problems can be simplified to the point where the merits of each option are intuitively obvious. Just as one sometimes must use shadow prices and multipliers to adjust an option's costs and benefits to reflect the general equilibrium feedback effects within the economic system, so must one sometimes model other types of interactions. Indeed, planning options can produce a variety of counter-intuitive impacts as the result of the interactions among several complex systems.

Technical complexity makes democratic decision making difficult, because voters may not understand, or may lose interest in the issues. Complexity makes public regulatory scrutiny difficult as well, because the planning logic becomes encumbered with myriad details and the paper trail becomes hard to follow. Potential interveners likewise have difficulty offering constructive input because of the barrier of complexity. In fact, complexity also makes it more difficult for the developer to make good decisions.

The potential for counter-intuitive impacts makes brainstorming for new options, a central part of any consensus-building process, more difficult. It suggests that simple *ad hoc* "horsetrading" of options while packaging them into strategies – "one of my favorites plus one of yours" – will not lead to superior outcomes. The impacts of options in interaction with one another need to be assessed because the final strategy may be much greater or less than the sum of its parts.

Electric Power Systems Are Complex

Electric power planning involves detailed discussions at the intersection of at least three complex systems: economic, technological, and ecological. Each of these systems has feedback loops that can lead to counter-intuitive results; interactions among the systems compounds this problem. A couple of examples are provided below to illustrate this difficulty.

Utility-sponsored conservation programs are widely touted to reduce total revenue requirements, which are (approximately) the sum of all customers' electric bills. Yet the price of electricity typically *increases* as the utility invests more in conservation. The explanation for this counter-intuitive result is that, yes, total revenue requirements do decrease, but the total number of units of electricity (kilowatthours) sold decreases even more. The price in ¢/kWh thus increases, even as the monthly bills of program participants decrease. This effect, when combined with the fact that non-participants' bills will increase, has inspired resistance to utility-sponsored conservation programs (Cape Cod Times, 1990).

Another example of counter-intuitive results in electric power system planning is the fact that the construction of clean generating capacity, such as a natural gas-fired power plant, does not guarantee that aggregate pollution will decrease. This power plant must not only get built, it also must get run more often than alternative dirtier power plants before total emissions will be reduced. Given equal combustion efficiencies, as long as natural gas costs more per unit of heating value than coal, then the clean gas-fired plant will operate far fewer hours per year than the dirty coal-fired plant. If there are many plants with different efficiencies and fuels, it is extremely difficult to qualitatively judge the environmental benefits of the gas-fired power plant. Detailed analysis of the economic dispatch ordering of all plants in the system may be necessary to understand actual impacts.

In Summary

Many existing planning approaches feature closed-door development of privately-optimal proposals that are only revealed to the public in the relatively late stages of regulatory approval and implementation. Such planning efforts can enter paralysis, brought on by the lack of a needed consensus on a project's merits. Indeed, consensus is a worthy goal for a planning process, but it is hard to achieve. The process must spur the inventiveness of its participants if this goal is to be reached. Controversy, uncertainty, and complexity are barriers that can stifle creativity, and prevent parties from reaching a consensus.

Electric power planning is a field that could benefit from the consensus-seeking approach. It also enjoys an abundance of controversy, uncertainty, and complexity, and is therefore a good candidate for experimental work in overcoming these barriers.

3. DESIGNING A PROCESS TO OVERCOME THE BARRIERS OF CONTROVERSY, UNCERTAINTY, AND COMPLEXITY

Controversy, uncertainty, and complexity are barriers that can stifle creativity and prevent the development of consensus in a planning process. The paralysis that results from failure to overcome these barriers has encouraged planners to look for ways to avoid these problems. One such prescription is presented here. In essence, I argue that what is needed is a planning process that is rooted in democracy, but that recognizes the value of technical expertise.

I begin this chapter by presenting an argument that in order to overcome controversy, the planning process should be opened up, and changed to be more consensus-seeking. I then discuss the results of an experiment that simulated open planning under conditions of uncertainty and technical complexity – a negotiated least-cost planning game played by sixty senior government regulators and utility executives. The participants' views on the pitfalls of such a process, and the need for a new analytic framework, provide guidance for an improved approach. The final sections of this chapter present my proposal for changing the role of analysis and matching it with a new procedural framework for open planning.

Changing the Process to Overcome Controversy

How can we prevent controversy from stifling constructive debate? Controversy may be overcome by ensuring that the concerns of all stakeholders in the debate are adequately addressed. Harnessing creativity to "make the pie bigger" is one step in this process. The other step is to explicitly acknowledge fairness as one of our planning criteria, and develop information that lets us gauge the relative merits of proposals from the points of view of each of the parties. To do this, it is necessary to open up the planning process, so that perspectives other than that of the project developer are brought to bear at the earliest stages of the effort.

In non-technical areas, public participation is widely held to be a good thing. Justifications for opening up planning processes to include wider public participation and consensus-building activities may be gleaned from several sources, starting with the planner's traditional, and fairly intuitive argument for the approach -- the best way to find out what people want and value is to ask them (Socolow, 1976).

A variety of perceptions of public participation can be identified. Participation as "policy" can be identified as a normative perception; opening up the planning process is desirable in and of itself. Participation as "strategy" implies its acceptance as a means for achieving other ends. Participation as "communication" suggests that improved information flows lead to better planning decisions. Participation as "therapy" can co-opt alienated groups into the mainstream. Participation as "conflict resolution" may (or may not) lead to reduced tensions and stable outcomes in controversial planning decisions (Wengert, 1976). Participation has many faces.

As was mentioned earlier, negotiation theorists argue that because formal judicial or regulatory hearings, such as public utility commission rate hearings or later courtroom interventions, are adversarial in nature, they typically result in zero-sum (win-lose) outcomes. In contrast, informal negotiated efforts can result in positive-sum (all gain) outcomes (Susskind & Cruikshank, 1987). For public utilities, one of the great problems with the existing planning, approval, and implementation framework is that initial decisions taken unilaterally by the utility may be overturned during later stages of the process, often at great cost in time and money. Consensus plans, on the other hand, are likely to lead to stable outcomes.

However, negotiated approaches to planning depend on the regular participation of diverse stakeholders to succeed. Their interactions allow safe brainstorming of ideas by separating the tasks of "creating" and "claiming" options. Initial options can be improved upon by "shuttling between the specific and the general," and the discussion may identity hybrid plans that everyone prefers relative to what was originally on the table. Tradeoffs among options can be explored in ways that allow stakeholders to estimate and update their BATNAs (Best Alternative To a Negotiated Agreement), in a low-risk setting (Fisher & Ury, 1981). All of this translates into increased public participation in the planning process.

In any planning effort, effective public participation is difficult to implement. Common problems range from tyranny of the majority, to the instability of decisions in a pluralistic democracy, to poor information and other barriers to optimal decisions, to apathy.

Adopting the perspective of public choice theory, one can think of an existing unsatisfactory planning process as an imperfect market, in which different actors are prevented from effectively articulating their preferences by a variety of market failures. The process can be made to operate more perfectly by transforming it into an open, or negotiated planning effort. To the degree that the negotiation operates like a perfectly competitive market, with shared information, access, low transaction costs, self-interested rational behavior, voluntary participation, equal power, and no market failures (externalities internalized), then, by analogy, it will produce Pareto-superior outcomes (Mueller, 1976). This defines a clear mandate for the participants to seek information (joint fact-finding) plus "refereeing" (mediation) services to keep the "market" working.

However, one can also picture an imperfect planning process as an unsatisfactory exercise in representative democracy. Again, an alternative forum that skirts some of the weaknesses of democratic decision-making may be needed; this could be the negotiating group. To the degree that the group emulates a democratic decision-making body by satisfying the five 'democratic' postulates of Arrow's impossibility theorem (unlimited domain, the no losers' test, transitivity, non-dictatorship, independence of irrelevant alternatives), it will not achieve social optima (Mueller, 1976). We must work to relax some of these postulates in order to achieve superior decisions.

We can broaden our interpretation of the no losers test (Pareto postulate) by allowing winners, losers, and mandatory compensation to occur. Relaxing the independence postulate is also both feasible and appealing, because it allows us to get away from making simple pairwise comparisons. Decision-making environments in which multiple options are compared may give better outcomes. Finally, relaxing the unlimited domain postulate allows groups with homogeneous preferences to make good decisions. The prerequisite for this is fostering consensus, or unanimity, in the group. The transitivity and non-dictatorship postulates should be maintained.

The prospects for achieving Pareto optimal decisions thus appear to be enhanced in negotiated, or participatory planning efforts. However, this appears to require explicit exploration of compensation, evaluation of multiple options, and consensus decision-making. The literature on public dispute resolution offers guidance on the design of consensus-building processes in the absence of technical complexity. Table 3-1 paraphrases one approach with proven usefulness for overcoming controversy in planning debates. An asterisk (*) has been added next to each task that may benefit from neutral analytical support. Transformation of the planning process to include these consensus-building steps will reduce the threat of paralysis in planning debates. A planning process that incorporates consensus-building steps such as these becomes, to some degree, an open planning process.

The core concept of open planning is that project developers (often private, investor-owned corporations) should seek to incorporate outside concerns directly into their planning processes. Rather than working in isolation to develop plans that are "optimal" from the firm's narrow point of view (Figure 3-1), planners should expand their analyses to consider the perspectives of the various groups influencing the plan's final viability. By introducing the viewpoints of potential interveners early in the planning cycle, the set of projects and programs comprising the developer's planning portfolio may be more easily and inexpensively revised to accommodate their concerns. The final package that is presented for regulatory approval and eventual implementation therefore may be more likely to gain wide acceptance (Figure 3-2).

The discussion above argues that it is highly desirable to include the concerns of different interested parties or groups in the planning process, in order to ensure that the project satisfies some expressed public need, in a way that people will accept, using the best achievable design. Interviews, review panels, and public hearings are the most common ways of doing this. In a sense, such efforts can be viewed as investments in political risk management by the developers. However, if the public is included in only a perfunctory way, then the benefit of this exchange will be minimal (Socolow, 1976). Involvement by interested parties in the planning process can become much more meaningful and fruitful if they are made an intrinsic part of the analytical effort (Holling, 1978).

Table 3-1: A Consensus-Building Process

Source: Based on Susskind & Cruikshank, 1987, pp. 95-150

Prenegotiation Phase

Getting Started (making the first move, role of neutral party, low-risk voluntary interaction, assessing Best Alternative To a Negotiated Agreement (BATNA)*)

Representation (conflict assessment*, stakeholding groups, credible spokespeople, unrepresented interests, networking, openness, size limits)

Drafting Protocols & Setting the Agenda (where meet? when? how often? how interact? media relations*, initial wide-ranging agenda*, clustering issues*, flexible/iterative process)

Joint Fact-Finding (information needs*, fact-finding protocols*, mutually acceptable sources*, valid assumptions*, uncertainties*, expected impacts*, historical precedents*, confidential information*)

Negotiation Phase

Inventing Options for Mutual Gain (focus on interest not positions*, inventing without committing*, brainstorming to increase range of options*, low-risk idea-sharing*, role of neutral in suggesting "laundered" options*)

Packaging Agreements (tradeoffs among options*, untradable components, different valuations of the same things by different stakeholders*, suggesting various possible packages*, identifying all-gain outcomes*)

Producing a Written Agreement (verifying mutual comprehension*, concrete document for review & ratification*, single-text approach*, contingency specification)

Binding the Parties to Their Commitments (self-enforcement mechanism, performance measures*, role of trusted neutral)

Ratification (communication with constituencies*, "selling" an agreement*, legitimacy & authority, splinter group management, regulatory consistency & ex parte communication constraints, contingent commitments)

Implementation or Post-Negotiation Phase

Linking Informal Agreements to Formal Decision Making (conversion to statute, bylaw, legal contract, executive order, administrative rulemaking)

Monitoring (checking compliance, objective standards*. changing circumstances)

Creating a Context for Renegotiation (conditions & procedures for reconvening)

** Tasks which in my view may benefit from neutral analytical support*

Figure 3-1: A Traditional Planning Process

Source: AGREA 1989 (modified)

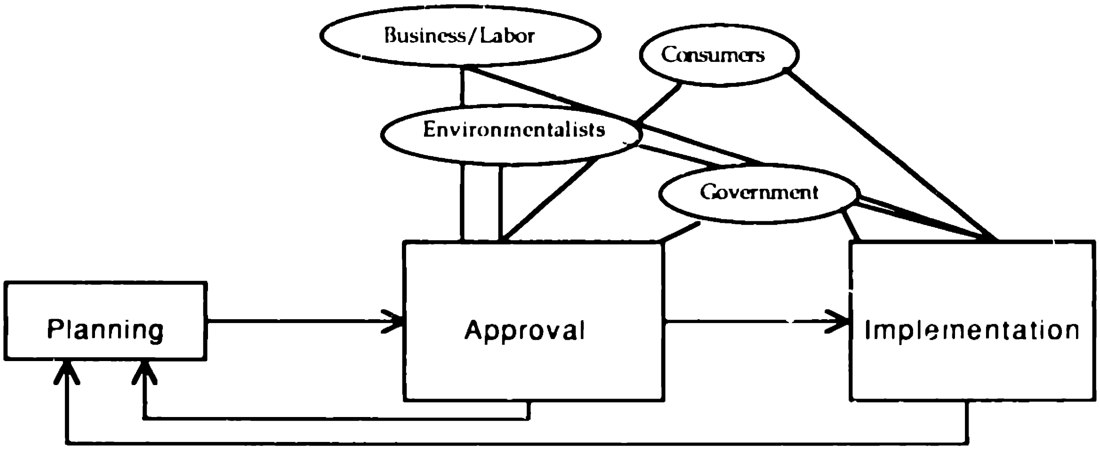
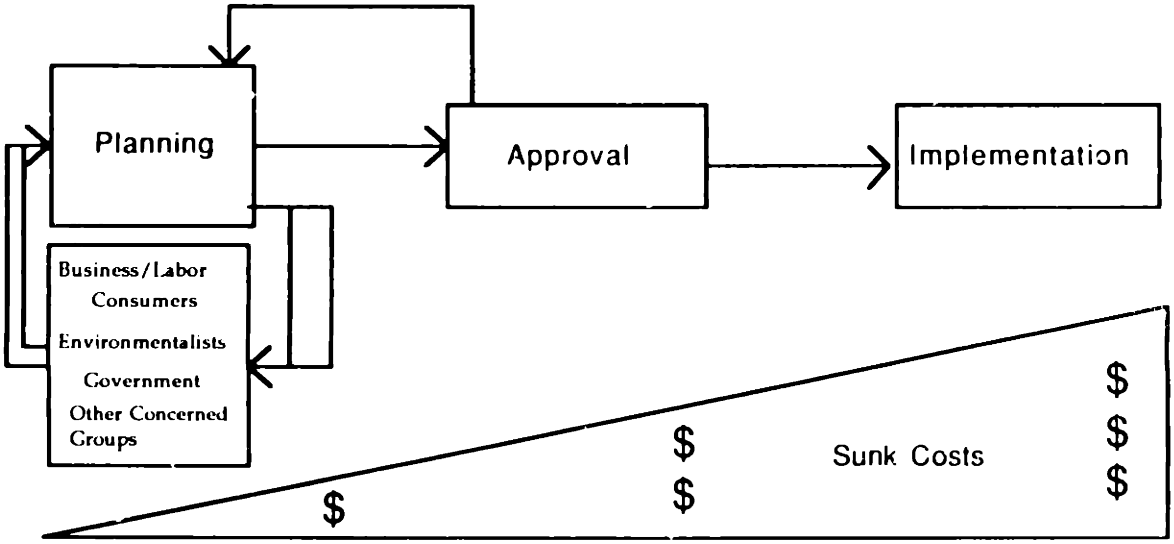


Figure 3-2: An Open Planning Process

Source: AGREA 1989 (modified)



Complexity, Uncertainty, and Participation – An Experiment

The impacts (environmental and others) of electric power planning decisions affect such a wide group of stakeholders that private utility decisions taken without consultation will not be stable; many will be overturned. Given this reality, the project developers need to ask people what they do and do not want. Regulators need to ensure that these questions get asked. However, electric power planning and similarly complex subjects often cannot be casually discussed or negotiated with any degree of success.

A number of authors have described the difficulties with introducing wider participation into highly-technical planning efforts. Ozawa and Susskind (1985) note that technical experts often seem to disagree about the established "facts," because of miscommunication, differences in the design of enquiries, errors in the enquiry, and differing interpretations of findings. The public cannot distinguish between superficial disagreements caused by the factors above, substantive disagreements, and the intentional use of distorting rhetorical devices. As long as expertise is introduced into the process in an adversarial form, then the public will have difficulty in distinguishing reliable facts from uncertainties, and factual questions from value questions.

Not all controversial projects will benefit from wider participation and the sharing of information. When the contentiousness surrounding a project is due to uncertainty, then activities such as joint fact-finding may play a role in developing a consensus. However, unless the experts in the fact-finding role have universal credibility, their efforts may instead increase conflict (Nelkin, 1977). Also, when the controversy stems from an obviously unbalanced incidence of costs and benefits among stakeholders, then further information may reduce the chance of settlement.

In order to better understand the challenges of implementing a more open approach to planning in the technically complex and highly uncertain electric power context, a negotiated least-cost electricity planning experiment was conducted. The opportunity to explore these issues with a group of senior decision makers came as part of an Institute on Reforming Electric Utility Rate Setting, Rulemaking, and Least-Cost Planning, sponsored by the MIT-Harvard Public Disputes Program, a project of the Program on Negotiation at Harvard Law School. More than sixty senior public utility regulators and power company executives from across the United States and Canada participated (see participants' list in Appendix A1).

A quarter of the meeting was devoted to playing and then discussing a negotiated least-cost planning game I wrote for the occasion (the complete text of the simulation is included in Appendix A2). In each play of the game, a half dozen players simulated a negotiated least-cost planning process. The game's general instructions established a context similar to that presently faced in New England, including impending shortages, a limited set of technological options, massive uncertainty and controversy.

To keep the game manageable, only five stakeholders were included in each group: the utility, an independent power producer, an environmentalist, a utility regulator, and a consumer advocate; plus a mediator. Each group had about an hour-and-a-half to attempt to reach a consensus decision regarding the next increment of capacity to be built. The limited set of options included natural gas, coal, conservation, load management, and extending the life of existing plants. Confidential instructions provided each member of the group with additional information about their preferences, the characteristics of the planning alternatives, and the important uncertainties. As in real life, different stakeholders' preferences often clashed, and both the amount and content of the information available to each participant differed.

With sixty participants it was possible to have ten plays of the game. A first goal of observing the participants' interactions was achieved by stationing volunteers at different tables, so that each could record the unfolding negotiation. During the debriefing session additional points came up regarding interactions at the remaining tables. A second goal of eliciting the participants' thoughts on the process of open planning was accomplished by getting them to fill out a questionnaire immediately after finishing the simulation. Questions soliciting the respondents' profession (government regulator, utility management, etc.) and previous experience with open planning processes (experienced, inexperienced) allowed cross-sectional analysis of the results by those factors. A high response rate and many thoughtful answers by the participants made this a particularly valuable exercise.

Of the ten plays of the least-cost planning game, eight ended in consensus and two in impasse. The details of the consensus outcomes differed from table to table, with two choosing a supply option (gas-turbine combined-cycle) and six some combination of demand-side options (conservation and load management). A discussion of selected outcomes, based on responses to a series of questions, follows below. See Appendix A3 for the complete set of questions.

Identify the hardest obstacles for you to overcome during this simulation. What would you expect them to be in your real job, if you participated in an actual negotiated least-cost planning process?

The participants were asked to rank order a list of obstacles. Higher priority obstacles received higher scores (5 = important, 1 = unimportant). They were asked first about the game, and then about what they would expect in real life. Correlations in scoring between the game and real life were moderate (see Spearman's ρ below, corrected for ties, with cases containing missing items removed); overall rankings were much closer. Obstacles receiving similar scores were grouped together to form five tiers. In order of decreasing score, they were as shown in Table 3-2.

Table 3-2: Obstacles to Consensus in Negotiated Least-Cost Planning Simulation

Obstacle n = 49	Priority in the game (sum of scores)		Priority expected in real life? (sum of scores)		ρ
Conflicting interests of parties	1	(186)	1	(196)	.727
Disparate values for non-dollar "intangibles"(pollution impacts, catastrophic risks, etc.)	2	(136)	4	(121)	.543
Conflicting technical information	2	(134)	3	(136)	.612
Polarization around different options	3	(115)	2	(146)	.443
Uncertainty about the future	3	(112)	3	(135)	.528
Differing perceptions of main issues	3	(109)	2	(152)	.396
Unequal background/ technical understanding	4	(81)	4	(124)	.513
Others (inadequate time, requirement for complete consensus)	5	(17)	5	(10)	.825

The highest priority obstacle, conflicting interests of parties, was ranked first priority by most individuals who voted for it, and was given the most votes in both the game and in expectations of real life. This obstacle is more general than many of the others on the list; it exists in all disputes, technologically-complex and otherwise.

The next most important obstacle in the game, disparate values for intangibles, had very different overall rankings in the game and in what was expected in real life. In both cases, most of those who voted for it assigned it 2nd or 3rd priority, but it got relatively more votes in the game context. In general it was given higher priority and received more votes from utility people than from government people.

Conflicting technical information received almost the same score in the game, and ranked higher in expectations of real life than the obstacle above. There was a strong consensus among those who voted for it that this obstacle should be a third priority, but it received many votes, which moved into the second tier in the game. Experienced people gave this obstacle both a higher priority and more votes than inexperienced people regarding expectations in real life.

The third tier in the game began with polarization around different options. There was little consensus on a particular ranking in the game, with experienced people, and utility people giving it higher priority than others. However, there was a strong consensus (on second place) regarding real life expectations. Uncertainty about the future also ranked in the third tier of obstacles. There was strong agreement on this ranking in both the game and expected real life contexts. Differing perceptions of the main issues closed out the third tier in the game, but scored in the second tier for expectations of real life. In the game there was fairly strong agreement on the third place priority.

Real life expectations included lots of first and third priorities, balancing out to a strong second on average. This bimodality seemed related to the tables at which people sat.

Concerns about unequal background and technical understanding brought up the rear in both the game and in expectations for real life. Experienced people ranked this slightly higher as an obstacle than did inexperienced people.

Which negotiating strategies did you try in the game, and which ones worked?

Before playing the game, the participants were introduced to a variety of negotiating strategies that have been used with success in other negotiating contexts. They were encouraged to try them during the simulation. In order of decreasing popularity, they were as shown in Table 3-3.

Table 3-3: Negotiating Strategies Tried in the Negotiated Least-Cost Planning Simulation

Strategy n = 52	Tried? (% of respondents)	Worked? (% of Tried)
Focus on interests, not positions	83%	77%
Invent options for mutual gain	71%	86%
Know your BATNA	58%	80%
Insist on objective criteria	37%	53%
Separate people from problem	29%	93%
Other (be positive; seek consensus)	2%	50%

The strategy tried most often, focusing on interests not positions, was much more successful for the government people who tried it (91%) than for the utility people who did so (58%). Other factors such as previous experience with negotiated planning, or game-specific effects of different mediators, roles, or tables did not did not reveal similar influence.

By contrast, the success of the next most popular strategy, inventing options for mutual gain, seemed most affected by previous experience with negotiated planning. It enjoyed a 95% success rate among experienced people, and a 78% success rate among inexperienced people.

The success of the third favorite strategy, knowing your BATNA, seemed to depend on the particular dynamics of the game. Mediator, role, and negotiating group mattered to the outcome.

The fourth favorite strategy, insisting on objective criteria, had a very low success rate that seemed to depend upon the game dynamics. Table by table the results were fairly consistent. Role had less explanatory power. The least favorite strategy, separating the people from the problem, enjoyed an extremely high success rate among those who tried it.

Was the mediator an important influence on the outcome of the game?

An overwhelming 88% of the respondents replied yes to this question. Of those who replied no, five out of the six were experienced with negotiated least-cost planning, and three of them were at the same table. The mediator's personal style seemed important to this outcome.

In real life, who would you trust to serve in the neutral, or mediator's role?

Since one of the goals of this research was to improve actual open planning processes, the participants were asked to rank different professions on their suitability for mediating this type of negotiation. It is important to note that dispute resolution professionals organized and taught at this event; their presence presumably affected the responses to this question. Respondents were instructed to give higher scores to the more highly-preferred mediators. Overall scores thus depended on both the number of people voting for that profession and the strength of their preferences. The results follow below, in order of decreasing overall score.

Table 3-4: Preferred Sources of Mediators

Profession	Tier	(Sum of Scores)
Dispute Resolution Professional	1	(216)
Technical Expert/Consultant	2	(157)
University/Academic	2	(151)
Government Official	3	(107)
Other	4	(21)
None	5	(6)
		n = 47

There was a strong consensus on dispute resolution professionals being the preferred mediators for negotiated least-cost planning efforts. This was revealed both in the rankings and number of votes received. The outcomes of the games seemed to influence peoples' views. Most of those who gave dispute resolution professionals a lower ranking sat at tables that failed to reach a consensus in the least-cost planning exercise.

Technical experts and consultants fell into the second tier of preferences. Feelings ran strongly here: most of those who voted for these professions marked them as their first or second choice. However, many people also chose not to vote for them at all. Experienced people dominated this latter group.

University and academic professions also enjoyed a second place ranking. There was a strong consensus on this; many people chose to give them their second place vote. Most of those diverging (downward) from this view sat at tables that failed to reach consensus in the game.

Government officials finished in third place in the polling. Again, there was a fairly strong consensus on this outcome, as indicated by the large number of third place rankings this profession received. As with others, this profession was less popular at tables not reaching consensus in the game. When asked to specify which government official would be most appropriate, several respondents mentioned public utility commission staff and one mentioned administrative law judges.

The "other" category drew responses in favor of retired judges, technically-proficient individuals trained in dispute resolution techniques, and the use of one's most respected adversary as the mediator.

The person voting for "none" actually ranked this option below dispute resolution professionals and technical experts/consultants, but above university/academics and government officials. This respondent (a government official) sat at a table that did not reach a consensus in the game.

The overall impression from this portion of the survey was that electric utility open planning processes shared some things in common with other types of negotiations, including concerns about the conflicting interests of the parties, polarization around different options, the value of mediation, and the usefulness of both standard negotiating strategies and dispute resolution techniques. However, the technical complexity of the subject appeared to add another layer of concerns. Obstacles such as conflicting technical information, disparate values for intangibles, and uncertainty about the future created special demands on the negotiating process. Technical proficiency as well as training in dispute resolution techniques appeared to have value in this context, and objective criteria for framing the discussion seemed harder to formulate. Even among well-meaning experts engaged in a simulation, rational discussions were difficult, and a consensus outcome was not guaranteed.

The Need for a New Analytic Framework – Some Expert Opinions

A more open planning process improves the potential for overcoming controversy, but, on its own, may still run into trouble in the presence of technical complexity and massive uncertainty. Additional innovations are needed to overcome these barriers. The dispute resolution literature provided some guidance, and the participants in the negotiated least-cost planning game also made valuable suggestions.

The disutility of the adversarial science approach was discussed above, and related options such as science court, scientific panels, and consensus-finding conferences also have profound weaknesses. The credibility of a science court depends entirely on the reputations of its judges; that of a panel depends on the diversity of its membership; while the participants in a conference lack authority to act on their findings. All of these approaches assume that "fact" and "value" questions can and should be separated; all of them leave the technical discussion once-removed from the stakeholders in the debate (Ozawa and Susskind, 1985).

Negotiation theorists argue that decision makers should discuss the normative aspects of scientific and technical work face-to-face rather than delegating it; thus they recommend strategies of information sharing and joint fact-finding (Ozawa and Susskind, 1985). Information sharing may reduce some of the uncertainty and complexity surrounding some planning problems, but other questions will require major joint fact-finding efforts. Such efforts need support structures to analyze options and uncertainties carefully, and evaluate outcomes in a consensus-building manner (Socolow, 1976; Bacow & Wheeler, 1984). This will provide the grist for producing efficient, equitable, sound, and stable plans.

While it is easy to state that joint fact-finding should take place in technically complex policy disputes, it may be difficult to specify how to to do this. An electric power system, for example, is so complex that accurately simulating the performance of a proposed option is beyond the capabilities of most of the stakeholders in the debate, in many cases even the utility itself. The system is so sensitive to uncertainty that slightly different input assumptions will change the relative attractiveness of the various planning options. Indeed, when the sixty participants in the negotiated least-cost electricity planning simulation were asked what the characteristics of the ideal analytic approach to support their efforts would be, their answers did not resemble any currently available computer package.

It is worth reviewing the analytic preferences of these experts based on their experience with negotiated planning. Their questionnaire responses provide useful guidance in specifying the details of an alternative analytic approach.

Please characterize the "ideal" analytic approach for use in an open, or negotiated planning process [by choosing how to end each sentence below].

In an effort to focus attention on analysis issues, I asked people to choose which way they would end seven sentences. Of the various parts of the questionnaire, answers to these questions provided the most direct prescriptions for what analysis in support of open planning should do. Previous questions elicited information about the relative importance of different activities; while here the respondents were given the opportunity to recommend design features rather than only reveal impressions about how things worked. Each sentence and its possible endings are shown in Tables 3-5 through 3-11. Answers are listed in order of decreasing preference. Respondents were instructed to choose only one ending for each sentence; however, some chose two. Both such votes were counted.

Table 3-5: Time Demands

Time demands of analytic effort on decision makers (not analysts) should be:

Answer	Rank	(Score)
"Minimal"	1	(24)
"Extensive"	2	(10)
Other (moderate; reasonable; sufficient; enough to understand context and implications of decisions)	3	(9)
		n = 43

The preferred answer to the question posed in Table 3-5 would appear to be obvious, but it still needed to be asked. One of the criticisms of negotiated planning is that it is time consuming for the principals, thus time demands could become a barrier to success. An important design criterion for an analytic technique is that it finds the type of balance mentioned in the "other" category choice: it must provide decision makers with enough useful information to understand the context and implications of decisions without becoming an unbearable time sink. Responses to this question seemed influenced by which table the respondent sat at during the game.

Table 3-6: Analytic Assumptions

Analytic assumptions should be based on:

Answer	Rank	(Score)
"Expert judgement"	1	(32)
"Group assumption-making"	2	(16)
Other	--	(0)
		n = 45

In Table 3-6, relatively more government than utility people voted for expert judgement. Although utility people overall also preferred expert judgement, relatively more of them voted for group assumption-making. The outcome of this question indicates that an important concern about open planning in the technically-complex electric utility context is that non-optimal plans may result. A number of respondents added comments to this effect in the margins of their questionnaires. They worried that, like other participatory political processes, open planning could turn into lowest common-denominator planning. They saw a value to expertise that ought to be preserved in whatever new planning approach was developed.

Table 3-7: Measuring Impacts

Measure impacts with:

Answer	Rank	(Score)
"Multiple measures, say $, SOx, LOLP"	1	(31)
"An aggregate measure, say $"	2	(12)
Other (multiple measures with ranking and weighting)	3	(1)
		n = 44

Table 3-8: Product of the Analysis

The analysis should:

Answer	Rank	(Score)
"Explicate tradeoffs among options"	1	(42)
"Identify the optimal choice"	2	(11)
Other	--	(0)
		n = 47

Voting for the question posed in Table 3-7 was consistent across respondent categories. A strong majority of these decision makers felt that high-impact projects such as electric power plants needed to be evaluated in terms of multiple attributes. They appeared to believe that aggregate measures were too opaque for use in a negotiating context where parties would not always trust numbers produced by analysts for their use.

The outcome of the question asked in Table 3-8 reinforces the importance of developing analytic techniques that are transparent to the negotiating parties. Black box models that produce a single "right" answer will not be credible to parties who a priori dislike that answer. Since stakeholders value various impacts differently, they are likely to have different definitions of "optimal." By exploring the tradeoffs between options, the negotiating group may be more likely to find (or invent) the socially-optimal and politically palatable option. The majority of those who voted for "optimal choice" above were not experienced with negotiated planning.

Table 3-9: Uncertainty Analysis

Regarding the future, the analysis should:

Answer	Rank	(Score)
"Analyze many possible scenarios"	1	(36)
"Carefully define most probable base case"	2	(15)
Other (provide for flexibility within a set framework)	3	(1)
		n = 47

In Table 3-9, the large degree of interest in multiple scenarios shows how important uncertainty has become as a planning concern in the electric power context. The only group that voted as a bloc for analyzing the most probable base case was legal counsels of utility companies. Majorities of each of the remaining professions voted for multiple scenarios.

Table 3-10: Decision Criterion

Options should be:

Answer	Rank	(Score)
"Rank-ordered (1st, 2nd, 3rd,...)"	1	(27)
"Valued in $ terms (greatest net benefit)	1	(25)
Other	--	(0)
		n = 45

There was no consensus on the right answer to the question posed in Table 3-10. The results did not associate strongly with any single factor. However, experienced people preferred rank-ordering (15 votes) over calculating net benefits (11 votes). Inexperienced people, on the other hand, had the opposite priority, liking rank-ordering (12 votes) less than net benefit calculation (14 votes). Within the experienced group, 3 utility people preferred rank-ordering while 5 chose the net benefits approach. Experienced government people reversed this pattern, with 8 choosing rank-ordering and 5 preferring the net benefits measure. The game may have influenced the outcome: role and mediator type seemed to matter. In particular, people who played the mediator's part strongly preferred rank-ordering. One experienced mediator reported that in the game people wanted to explore the dollar values of options, but once they were on the table these values were of little use because they disagreed with one another.

Table 3-11: Mediation Skills

Successful mediation must be:

Answer	Rank	(Score)
"Technically-substantive"	1	(34)
"Process-only"	2	(19)
Other (informed but non-partisan; both; either; a combination)	3	(13)
		n = 45

Concerns about the technical complexity of electric power planning revealed themselves again in the answers to the question raised in Table 3-11. A strong majority of the respondents preferred a mediator with technical knowledge over one who could only enhance the process. The game had an effect on the magnitude of this outcome: respondents from tables with more-judgmental mediators voted especially strongly in favor of technically-substantive mediators, although majorities of both groups preferred that choice.

Having elicited design criteria for analysis to be done in support of negotiated planning processes, I then asked the group who should do that work. Respondents were told to give higher scores to more-highly preferred sources of analysis. The overall scores depended on both the number of people voting for that source and the strength of their preferences. The results are shown in Table 3-12, in order of decreasing overall score.

Table 3-12: Sources of Analysis

Source of Analysis	Tier	(Sum of Scores)
Technical Expert/Consultant	1	(290)
University/Academic	2	(225)
National Laboratory	3	(201)
Blue Ribbon Committee	3	(197)
Utility Planning Department	4	(160)
Government Agency (incl. PUC)	4	(151)
Dispute Resolution Professional	4	(118)
None	5	(18)
Other (group-picked committee)	5	(9)
		n = 48

There was a strong consensus on the first choice of technical expert/consultant, both in individuals' scores and the number of votes.

University/academic sources were the second favorite overall, although the individual scores were more diverse. There was a fairly strong consensus among inexperienced people on the second tier ranking, while experienced people seemed more polarized, ranging from first place votes to no vote at all. Tables not reaching a consensus in the game did not like this source as well as others.

National laboratories were in the third tier as a source of technical information. There was wide dispersion on individual rankings, although their mode was third place. This source was somewhat more preferred among inexperienced people.

Blue ribbon committees also landed in the third tier. This was the result of getting a large number of votes, many of which assigned a fairly low priority (fourth or fifth place) to this option.

Utility planning departments came in fourth, with a very wide dispersion in the individual rankings. These ranged from first through seventh place, and half of the group chose not to vote for them at all. Not surprisingly, this option was more preferred by utility people than government people.

Government agencies also received a fourth tier assignment. In almost a mirror image of the results for utility planning departments above, this option also had a wide dispersion in the individual scores. As above, these ranged from first through seventh place, with half of the group choosing not to vote for them at all. This time, government people preferred the option more than utility people.

Dispute resolution professionals closed out the fourth tier, receiving few and widely dispersed votes. This option was more preferred by government than utility people.

There were a few votes for the "none" option, and one suggestion in the "other" category for a group-picked committee to conduct analysis.

Both neutrality and technical expertise appear to be important criteria to consider when choosing the analysis team. When asked what the major tasks of the analysts should be, the participants in the game named several. These include the need to identify issues of primary importance to the planning effort, and to get the parties to share information with one another in ways that reveal their preferences, for generic attributes if not for specific options. Another major job of the analyst is to invent packages of options for the group to discuss. Equally important is the job of helping the parties to find agreement. Steps in this process include analyzing shared information to find acceptable options, uncovering common ground beneath conflicting statements, and finding ways to sort through or prioritize options that are acceptable to all parties.

In summary, the participants in the negotiated least-cost planning simulation felt that analysis should provide them with enough useful information to understand the context and implications of decisions without making unreasonable time demands. The value of technical expertise needed to be recognized and preserved in this process. The widespread preference for a technically-substantive mediator underscored this criterion. The special needs of a consensus-building process recommended the use of multiple measures for evaluating impacts, and careful exploration of the tradeoffs among options. Uncertainty about the course of future events suggested a need to analyze many possible scenarios.

Changing the Role of Analysis

Open planning processes have special information needs in the context of complex systems such as electric power networks. Interactions between system components can cause options to perform counter-intuitively, thus limiting the amount of simplification that can be permitted when discussing planning choices. Likewise, uncertainty makes definitive analysis difficult because results must be subjectively interpreted. Satisfying the interests of multiple participants having diverse points of view, and getting agreement on modeling assumptions, can impose additional demands on the approach taken. Controversy, complexity and uncertainty together provide a tremendous challenge that is imperfectly met by traditional analytical tools.

A key piece of such an open planning effort is to provide technical information in a way that stimulates creative discussion rather than paralyzing it. Information should help the parties understand how the economic, technological, and ecological systems work, so that they can find the strengths and weaknesses of project proposals that have been put on the table. In doing so they will be able to identify better ways of achieving the same goals, and develop projects that accommodate the concerns of more of the parties.

In the past, much of the environmental and economic impact assessment practice has been limited to reactive analysis, justifying or refuting decisions that had already been made (Holling, 1978). Even the "adversarial science" approach has typically served more to bring ongoing projects to a halt than to stimulate creativity in the initial design phase of new projects. In many cases, environmental impact assessment efforts have: (1) been a handle for delaying a project, (2) not provided information that was credible to all parties, (3) occurred too late in the project implementation cycle to serve as a stimulus to creative thinking about project options, (4) been expensive, and (5) been largely unread. Interveners in controversial projects typically have not affected implementation until quite far along in the planning cycle, resulting in higher costs of delay.

Therefore, along with the development of an open planning process, there is a need to invent an analytic approach that provides useful and timely input to the joint fact-finding effort. This means: (1) introducing potential interveners' concerns early in the planning cycle, (2) ensuring that the analytic work is believable to all participants, (3) measuring impacts along the variety of attributes that the parties individually care about, (4) having enough modeling sophistication to simulate the interactions between parts of complex systems, (5) acknowledging uncertainty up front instead of relegating to *ex post* sensitivity analysis, (6) working towards a shared understanding of issues relevant to the planning process, and (7) seeking a consensus on preferred strategies.

An Alternative Planning Approach

The diverse thoughts presented up to this point in the chapter may now be pulled together into an alternative planning approach. Both the process and the role of analysis need to change from currently accepted practice.

How can we prevent controversy from stifling constructive debate? We must open up the planning process. Using a procedural framework for principled negotiation, most likely with the assistance of a facilitator or mediator, can ensure that the concerns of all stakeholders in the debate are adequately addressed, because they will be at the table.

How can we deal with uncertainty? By exploring a range of possible future outcomes during the planning process, and testing the robustness and flexibility of our planning options against them. Of course, since the range of possible future events is quite subjective, this must be done in a way that provides useful information to parties with widely differing expectations of the future.

What about technical complexity? We have to maintain a high level of expertise in the planning effort, and not let it get diluted during the process of addressing the problems of controversy and uncertainty. Analytic strength, acknowledging both the systemic context and the pervasiveness of uncertainty, must be meshed with the procedural strengths of assisted negotiation. An expert analysis team must serve the planning group.

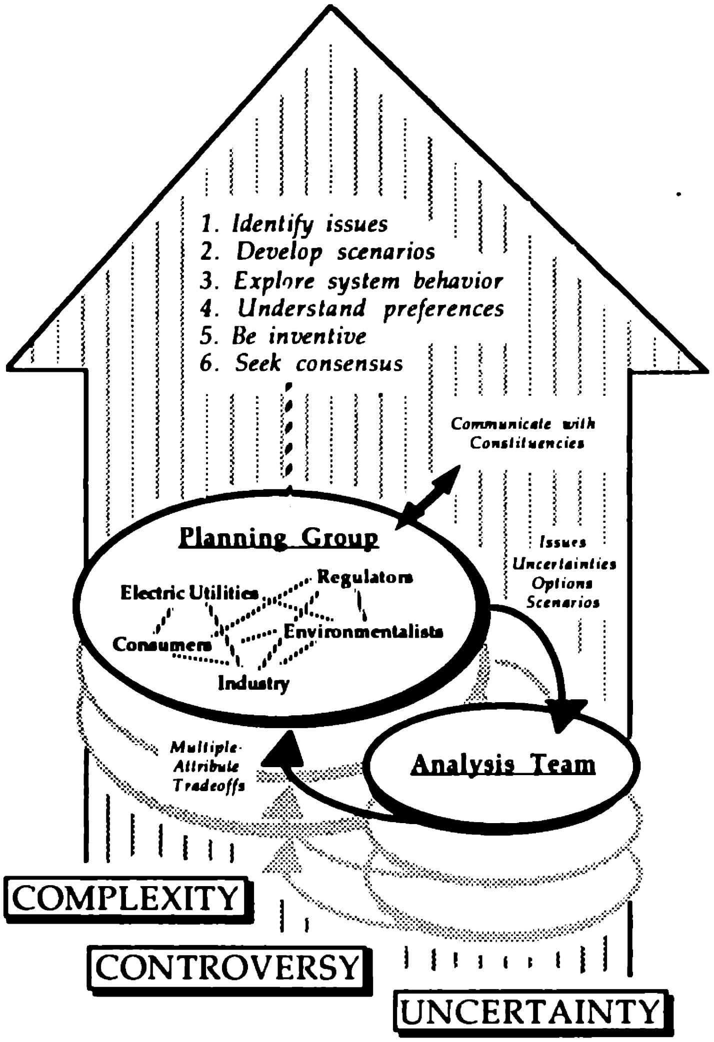


Figure 3-3: An Open Planning Approach

The basic premise of the approach developed and tested in this research is that better strategies can be found if all of the parties to a problem such as an electric power planning debate – utilities, environmentalists, regulators, and customers – work together at the earliest stages of project planning. An analysis team should support this planning group in its efforts (see Figure 3-3). Joint fact-finding about possible options and uncertainties, the behavior of the complex electric power system, and the cumulative impacts of planning choices can encourage creative thinking among the parties. This in turn can lead to better project proposals. By eliciting the concerns of all parties affected by utility investment decisions, this "open" planning process can identify project proposals that are not only privately efficient, but also fair, stable, and wise in a broader societal context.

Procedural Framework

The planning effort needs to be set up in the form of a *public* public policy analysis exercise. The diverse concerns of participants in the planning debate need to be channeled into analyzable form. The goals of the analysis, objectives, issues, uncertainties, attributes for measuring acceptability, options available, impacts of different choices, criteria for choosing, and means of evaluation must all be identified during the group's interactions. This approach will reduce the "black box" nature of the analysis work, and build the group's confidence in the results. It will also tap the creativity of the participants, and allow them to invent better options than those currently on the table.

While the goal of an open planning process is to acknowledge the concerns of all stakeholders in its outcome, it is important to remember that only one entity will be the actual project developer. It is likely that the developer is also the "client" that sponsors the negotiated planning exercise and its associated analytical efforts. The analysis technique thus must be oriented towards the notion of a primary client surrounded by secondary stakeholders, if it is to be useful. The analysts should be able to extrapolate from lessons learned during brief interactions with the stakeholders to subsequent strictly analytic tasks.

This orientation requires the analysts to walk a fine line between serving the client's needs and maintaining a neutral posture. Strategic behavior on the part of the developer must be anticipated and defused. A mindset emphasizing "communicative action" geared toward mutual understanding must be fostered in place of more traditional, self-interested "strategic action" (Ulrich, 1988). The focus on communicative action is useful to remind us that the planning effort is a two-way street: the analysts and developer need to produce information of value to the assembled stakeholders, and at the same time elicit their preferences on a variety of topics for later use.

Table 3-13: Procedural Framework for Open Planning

1. **Identify issues** to focus the analysis upon, **and attributes** by which to compare the performance of different options.
2. **Develop scenarios** examining the performance of combinations of options (strategies) across a variety of uncertain future events (futures).
3. **Explore system behavior** by observing the multiple-attribute tradeoffs between strategies, for a variety of possible uncertain future conditions. Develop better strategies based on this information.
4. **Understand participants' preferences** by observing which strategies interest each party, what uncertainties concern them, and how they weigh the various attributes relative to one another. Develop strategies with the potential for consensus based on this information.

Repeat........

5. **Seek consensus** on a favored strategy.

The interactions between analysts and stakeholders should be structured so that four steps carry the group through a full iteration of the planning process (Andrews et al, 1990; Connors et al, 1989), with consensus representing the desired final outcome. These steps are listed in Table 3-13.

Each of these steps is discussed in detail in the next chapter, and then applied to actual planning situations in the following chapters. This approach offers the potential to overcome planning paralysis brought on by controversy, uncertainty, and technical complexity. It is designed to spur the inventiveness of the participants in negotiated, collaborative, or open planning processes.

4. SCENARIO-BASED MULTI-ATTRIBUTE TRADEOFF ANALYSIS

The open planning approach outlined in Chapter Three proposes regular interactions between stakeholders in the debate and an analysis team. These groups would execute a multi-step *public* public policy analysis exercise, first identifying issues to focus the analysis upon, and then attributes by which to measure progress. Next they would develop scenarios to examine a wide range of options across a variety of uncertain future events, followed by an exploration of system behavior designed to stimulate creativity in developing better strategies. The fourth step centers on understanding the participants' preferences so that strategies with the potential for consensus may be identified. The final step is to seek consensus on a preferred strategy.

The analytic tools used to support this type of effort are likely to affect its success. This chapter therefore provides some background on the analytics of public project evaluation, and the relevance of different techniques to a context of controversy, complexity, and uncertainty. It then provides further details of a technique developed specifically for this context – scenario-based multi-attribute tradeoff analysis.

Theoretical Background

Much of the theoretical basis for planning tools that have been developed to date derives from the microeconomics of project evaluation. When the neoclassical assumptions of perfect markets hold (i.e., atomistic perfect competition, no externalities, no distortions, rational self-interested behavior, perfect information, perfect mobility, unanimity) then traditional approaches to project evaluation are adequate. Under such conditions, the Pareto criterion (no losers test) provides a nearly irrefutable decision rule.

However, as market imperfections and failures creep into the picture, then neoclassical economists must stretch their paradigm and increase the normative content of their analyses, first by reverting to the Kaldor-Hicks criterion (net social benefit), and second by introducing shadow prices to correct for distorted or non-existent prices.

The standard cost-benefit decision rule used in public project evaluation, the Kaldor-Hicks "potential Pareto improvement" criterion (or hypothetical compensation rule), will not provide an adequate measure of social welfare improvement for a contested project in a democratic society. That screen passes projects that have winners and losers, as long as the net benefits are positive (Mishan, 1982). However, the fact that some project provides an aggregate welfare improvement will not placate those who lose something by its implementation. If there are losers and they have adequate political clout, they will stop the project.

Compensation of losers by the winners, or redesign of the project to have no losers, appears to be mandatory, if social consensus on a favored project option is necessary for successful implementation. For example, this appears to be needed for electric power plans in New England. An approach that would permit tradeoffs to be explored, redesign to occur, and compensation packages to be developed appears to be necessary in such a context.

A different, context-oriented "decision rule" must be developed to provide a basis for developing analytical tools to support the tradeoff discussions. This requires a rule that is closer in spirit to the Little criterion, which specifies that both an aggregate welfare improvement and some (unspecified) equity effect must be achieved (see Hagman et al, 1978; O'Hare et al, 1983; and Schofield, 1987). Specifically, I contend that the rule needed for an option to be preferred in a tradeoff analysis, or negotiating situation, is that "the gainers must adequately compensate the losers, and, after implementation, still remain better off."

This "negotiation" criterion is more restrictive than the Kaldor-Hicks rule used in economic cost-benefit analysis, because a way to accomplish the compensation must be found before the proposal can be accepted. However, it is much less restrictive than the Pareto criterion ("no losers" test) engendered in the theory of perfect markets, because non-price compensation is permitted. Its key operative features are that it is context-oriented, it forces all stakeholders in a decision to be inventive, explore trades (compensation), and try to find "all gain" solutions (Hagman & Misczynski, 1978; O'Hare, Bacow & Sanderson, 1983).

It is important to make clear that the trades, or compensation, can be made in any combination of units/commodities/currencies that satisfy the parties involved. If individual utility functions are not aggregated, no valuation problem arises, and dollars can be traded for tons of SO_2 emissions, for example, at whatever context-specific rates all of the parties will accept. However, since it is context-dependent, this criterion cannot be formulated into a general "decision rule" that can be mechanically applied. Instead, it merely highlights the types of information required for a negotiated planning process to proceed: explicit representation of the multiple-attribute tradeoffs implicit in each planning choice, and analysis of impacts from the different viewpoints of each of the participants.

Cost-benefit analysis and other single-criterion, static, optimization-oriented techniques that lean on shadow pricing have limited applicability in the design of contentious projects. Those techniques may burden the analyst with too many value judgements that are really the responsibility of the decision makers. Thus, a systematic basis for choosing a planning technique should be applied that keeps track of the role of the analyst versus that of the decision makers.

I would approximate this basis as follows, asking the analyst a contingent series of questions: (1) Are there non-market impacts, or distortions of the perfect market model that result from this project? If no, then use cost-benefit analysis or related tools based on generalized decision rules; if yes, then ask (2) can the impacts be quantified? If no, then use a decision-analytic tool for multi-criteria evaluation of both quantifiable and non-quantifiable criteria; if yes, then ask (3) is uncertainty irrelevant? If no, then consider risk, noting that individual perceptions vary. Define probabilities for use in expected value calculations, thus increasing the normative content of the analysis, or elicit participation in developing these probabilities as a way of sharing responsibility for these normative decisions. Add probabilistic or other techniques for decision analysis under uncertainty. If yes, then ask (4) is there a social consensus that all worthwhile options are on the table? If no, then use the raw information on impacts to spur inventiveness, generate better options, and winnow out dominated options; i.e., find the Pareto frontier before progressing further in the decision making process. If yes, then ask (5) is there a social consensus on the valuation of the impacts? If no, then introduce public participation into the process of formulating shadow prices, and/or switch to multi-criteria evaluation; if yes, then ask (6) can all impacts be aggregated to a single net benefit number? If no, then use multi-criteria evaluation; if yes, then proceed with cost-benefit analysis. Each of these questions flags a point in the evaluation where normative bias may be introduced by the analyst.

Decision scientists developing optimization tools typically try to develop objective functions simulating their clients' preferences (or utility functions) with a vector of weighted attribute measures. For example, traditional electric utility planning has focused only upon the objective function of the company. That narrowly bounded process has broken down in the face of interventions by environmentalists, regulators, and others; thus, in that context, a different approach needs to be tried.

Alternative approaches exist. Planners may: (1) attempt to develop a social welfare function representing society's aggregate best interest, and use that for optimization exercises in lieu of the company's objective function, (2) develop separate objective functions for each stakeholder group, and do iterative optimizations in the hope that they will converge, or (3) abandon mechanical optimization efforts and present the tradeoffs, in multiple attribute terms, directly to the stakeholders so that they may negotiate a preferred solution (Keeney & Raiffa, 1976).

Attempts to develop a social welfare function, as in (1) above, are fruitless when disagreements exist between stakeholders; the validity of that approach rests upon an assumption of unanimity. If consensus does not initially exist, then plans optimized around even a regulatorily-defined social welfare function will not satisfy some groups; and they will be challenged.

Decision scientists point out that information has value in decision-making (Keeney, 1982). For example, better information about options and the effects of uncertainty allows stakeholders to better define their preferences. Further, better information about stakeholders' preferences allows planners to develop better strategies. Most parties will be willing to invest time and resources to get better information.

This suggests that people's preferences change, in a Bayesian sense, as new information is received (Keeney, 1982). Thus stakeholder objective functions should not be modeled statically, or aggregated into a fixed social welfare function. Instead, individual preferences should be elicited through a long term, iterative process. Analysts taking the approach described in (2) above would spend a great deal of time interviewing and re-interviewing stakeholders, seeking glimpses of their constantly changing preference maps. Plans optimized in this manner could certainly satisfy more stakeholders; if the data and modeling approaches were widely perceived to be credible, and all possible options were already on the table.

However, in an era of "adversary science," stakeholders often distrust each others' data and models (Ozawa & Susskind, 1985). Only by building a common data base, getting general agreement on modeling assumptions and tools to be used, and making the process transparent and easy to follow, can the results obtained from analysis efforts gain wide credibility. Some of the most controversial stages in any multiple attribute analysis effort are the valuation of intangibles (such as visual blight) and the aggregation of many dissimilar attributes into a simpler index that provides a basis for decision-making. Efforts to construct utility or objective functions that aggregate multiple attributes into "utils" may not be accepted unless the stakeholders understand every previous step of the modeling process (Keeney & Raiffa, 1976).

It is also rare to find that all possible options are on the table at the beginning of a planning effort. Initially, proposed options may include only those of interest to one party, such as the electric utility, or they may be expanded to include the extreme opposites over which stakeholding groups already have become polarized. However, the more satisfactory final options, those around which consensus can form, are typically hybrids that combine the best features of several earlier options. These may only be discovered through an iterative process that allows such hybrids to be built by stakeholders interacting creatively with one another (Raiffa, 1982).

The approach outlined in (3) above may be the best choice when disagreements exist among stakeholders, "adversarial science" plays a role in policy discussions, and all possible options are not initially on the table. By encouraging the stakeholders to negotiate the planning proposal, rather than allowing the utility planners to optimize it in relative isolation, mutually more satisfactory results may be obtained. By involving the various parties in the analytical work from the outset, its results may be more credible. By presenting results in a multiple attribute, tradeoff format, controversial valuation and aggregation problems may be sidestepped, and stakeholder objective functions will not have to be rigidly defined. Better options may be invented during this iterative process, and the planning proposals that result may demonstrate both political and economic viability.

To the degree that participants represent the interests of the stakeholders in the debate, and their (unmapped) objective functions either incorporate or are identical to those of their constituents, a negotiated project evaluation arrangement can produce socially desirable outcomes.

The overall point of this section is that some types of projects need fairly context-specific planning criteria and complementary analytic techniques. Tools built to optimize a project design around a general decision rule, such as "least cost," will yield inappropriate results in many cases. The general Pareto criterion is too restrictive for decisions on many (especially public) projects, and the general Kaldor-Hicks criterion may be too lax. Specifically, contentious projects must provide not only a net social benefit, but also adequate compensation of losers by winners to ensure that a consensus forms to allow the project to go forward.

Such compensation arrangements will be highly context-specific, requiring an "open" or negotiated planning approach. If there are technically complex issues to be resolved, then negotiated project evaluation will require substantial analytical support. Ideally, the analytic tools for use in such an effort would acknowledge uncertainty when it pervades a planning process, the multiple points of view of the project's different stakeholders, and the conditional nature of any consensus on the valuation of project impacts. These qualities are not found in most present project evaluation tools.

Review of Existing Approaches

In this section I review existing project analysis tools and the ways in which analysts interact with decision makers when using them. An assessment of the state of the art for relevant analytic techniques serves as a launching point for the enhancements that I have developed.

The design options for many public projects need to be evaluated across multiple dimensions, such as cost, environmental impacts, and quality of service. This is especially true where the project is large, and has significant spillovers or distributional impacts. Such multi-dimensional analysis may be difficult, if some impacts are hard to measure or value. Public participation may be desirable, if controversy or uncertainty surround the measurement and valuation of various project impacts. Different analytic approaches are appropriate for different levels of project size, spillovers, impacts, and public participation. Choosing an appropriate approach requires the planner to evaluate the project's political, as well as economic and physical context.

One of the most challenging tasks in public decision-making is to weigh the tradeoffs between the varied costs and benefits of diverse project options. The many impacts associated with each option may be difficult to measure, hard to value, and nearly impossible to aggregate into a common numeraire that would provide a basis for choosing among alternatives. An added challenge for the public planner is to ensure that the project meets the needs of those it serves. A variety of approaches exist that accommodate the multi-faceted character of these planning problems, and encourage some level of public participation. Each is suitable for a particular planning context. I will briefly review the nature of multi-dimensionality and participation in decision-making, and then discuss the strengths, weaknesses, and applicability of certain analytical approaches.

Multi-Dimensional Impacts and Public Decision-Making

Many public projects have profound impacts along several dimensions. An extension to a water supply system, for example, has clear monetary costs; payments must be made in order to get trenches excavated, pipes laid, and pumps installed. However, it also may have environmental impacts if land gets flooded to provide a new reservoir, or public health impacts if lead pipe is replaced with steel or chlorination reduces coliform bacteria counts. Likewise, the quality of service may be affected, as delivery pressures are increased, or turbidity reduced. Social impacts may also occur, such as growth that is induced by the extension of service. When evaluating design alternatives, a decision maker must somehow compare their impacts across all of these dimensions in order to choose a preferred option. This exercise may be broken into separate steps -- measurement, valuation, and aggregation (Elliott, 1981).

Some impacts may be easy to measure. The amount of trenching (cubic yards of earth) is quickly and precisely quantified by an engineer. Similarly, the number of acres to be flooded for a new reservoir easily may be quantified. However, the turbidity of the water leaving a new filtration plant is much less certain; it depends on seasonal changes in water chemistry, acid rain effects, and other factors that are hard to predict. The reduction in brain damage to children that results from removing lead piping is even more uncertain; being undetectable until years after the damage was wrought, and, even then, difficult to quantify. Measurement of direct impacts thus varies in quantifiability, and in the level of uncertainty surrounding the estimates.

Valuation of the impacts that have been measured presents an even greater challenge. Of course, some impacts are easy to value, such as the cost of piping and pumps. The markets for these materials work quite well in most countries, and there is a social consensus on their value, such that they can be defined wholly in monetary terms. However, there may be much less social consensus on the value of less turbid water, or of avoiding highly uncertain levels of brain damage in children. Intangible impacts, lacking a market value, may be valued differently by different people.

Aggregation of the values for a project alternative's many impacts may be necessary to effect a decision among alternatives; otherwise, the amount of information presented may baffle the decision maker. The degree to which dissimilar attributes may be aggregated depends in part upon the analyst's success in valuing impacts using a common numeraire. For example, it may be possible to value both piping and flooded land in dollar terms, if there is a working market for both (no externalities). Conversely, dollar values of turbidity and brain damage may not enjoy a social consensus, and thus may need to be reported separately. Key aspects of multi-dimensional decision-making thus include the uncertainties surrounding the measurement of estimated impacts, the degree of social consensus accompanying their valuation, and the level of complexity attending the aggregated results.

Public Participation

As was discussed above, the appropriate means and extent of public participation varies according to the planning context. If there is widespread consensus on an issue, and that is recognized by the planner, then minimal public participation may be required. For example, public hearings on the prices of piping and pumps may do little to improve the decision-making process. On the other hand, where discord or uncertainty exist, then participation may have greater value, when choosing, for example, whether to prioritize a chlorination investment over efforts to remove lead pipe. Large projects with significant externality effects may benefit from meaningful public participation that provides stability to the decision-making process.

Public participation can include a wide range of activities. Simply by electing public officials, the public assigns a mandate to them and their policy prescriptions. Project-specific hearings, review panels, interviews, or surveys provide other forms of participation. Iterative planning processes, in which public spokespeople play an integral role, represent yet another approach. The approach chosen needs to be tailored to the circumstances surrounding the project.

Analytic Approaches

Several different methods may be applied when evaluating planning options whose impacts unfold along multiple dimensions, and the concerns of interested parties may be included in different ways. Variants of cost-benefit analysis and multiple criteria decision analysis represent the two major families of techniques discussed below.

Note that this discussion focuses on decision-making tools, i.e., those incorporating explicit decision rules for selecting preferred options. Other methods, such as input-output analysis, econometrically-based economic general equilibrium models, pollutant transport models, or epidemiological receptor-damage models, are extremely valuable for measuring a project's varied impacts. However, they typically serve as intermediate inputs into the final decision-making tool.

Engineering and Private Cost-Benefit Analysis

Drawing on my previous discussion of normative content and the value of cost-benefit analysis, we can see that non-economic approaches to cost-benefit analysis are useful when: (1) spillovers are unimportant, (2) all impacts are measurable and can be valued in dollar terms or held constant, (3) goals and standards are clearly defined, and (4) a social consensus surrounds the project.

Starting with the narrowest point of view, engineering-economic analysis typically measures a project's cost-effectiveness, holding perceived benefits constant while seeking design options that minimize costs. For example, the engineer takes this approach when selecting pumping arrangements that provide a specified water pressure and flow rate. Alternatively, given budget constraints, an analyst may choose to take the other tack of maximizing benefits for a fixed cost. For example, the engineer will install as large a water main as the budget will allow, in order to provide capacity for future system growth. Both of these approaches assume that the only public participation needed has already occurred, in setting target benefits or budget constraints.

The slightly broader point of view engendered in private cost-benefit analysis is widely used by profit-maximizing firms, and in public agencies for small projects. This method seeks to identify options that maximize net benefits to the firm or agency, within legal constraints set by society. It assumes that no externalities exist that will affect outside parties.

The techniques outlined above ignore, or hold fixed, non-quantifiable and intangible attributes in the evaluation process; and typically discount future costs and benefits at market interest rates. They often assume that further public participation is unneeded, because they are meeting pre-determined goals, or complying with publicly accepted standards, for least cost.

Economic and Social Cost-Benefit Analysis

Economic and social cost-benefit analysis can be viewed as extremely useful tools when: (1) the planner has a public mandate to make independent decisions, or where democratic decision-making and participation is of little concern, as with many development projects; (2) most of the important impacts can be valued in dollar terms, even if externality values must be estimated with shadow prices; and (3) uncertainties surrounding major impacts are minimal.

Economic cost-benefit analysis, the favored approach of public policymakers, uses a broad measure of social benefits, that of aggregate welfare. This approach seeks to identify options that increase aggregate social welfare, i.e., promote overall economic efficiency. Social cost-benefit analysis puts more of a policy spin on the economic cost-benefit objective, by weighting the interests of certain groups in the social welfare function, and developing a social discount rate for weighting future impacts. This allows equity concerns to be made part of the project selection criteria (Schofield, 1987).

The analyst seeks to value as many impacts as possible in dollar terms, so that they may be aggregated together into a single benefit-cost ratio. Shadow pricing of intangibles is one of the greatest analytical challenges under this approach. For example, when attempting to value water clarity, the analyst may elicit peoples' willingness-to-pay (or their willingness-to-accept compensation) for different levels of turbidity by survey or interview. More difficult would be assessing the value of avoiding brain damage in a child (by replacing lead pipe). This could be done on the basis of reduced lifetime income, increased social security burden, parents' willingness to pay to avoid this problem, or many other ways, each of which may produce a different estimate.

Economic and social cost-benefit analysis can be opened up to public participation by seeking consensus on the shadow prices to be used for intangible impacts. Surveys, interviews, and advisory panels may be useful for eliciting peoples' opinions on these valuation problems. Alternatively, the most difficult-to-value intangibles can be left in their raw form, and accompany the benefit-cost ratio in the final output. They may then be used as additional, parallel criteria upon which to base the selection decision, which presumably would acknowledge the stakeholders' valuations of these multiple factors.

The key strengths of a cost-benefit approach to project evaluation are that it is systematic (i.e., replicable and teachable), explicit (specific costs and benefits are identified and quantified), directional (the process narrows the field of choice), and progressive (planners are put in a position to create better alternatives next time).

The main weaknesses of this approach include: (1) a necessary assumption of social unanimity, such that aggregate social welfare improvement can be used as a decision rule; (2) the possibility of not counting (or miscounting) intangible impacts; and (3) the difficulty of characterizing how options will perform under a variety of uncertain futures.

Multi-Objective Decision-Making

Decision analysis provides an alternative to cost-benefit analysis for making project choices. It is a relatively prescriptive paradigm that offers systematic approaches for choosing a course of action in uncertain circumstances. It is less normative than cost-benefit analysis in that it emphasizes analytic strategies over specific decision rules. The focus here is on multi-criteria decision-analytic tools that have been used previously to support decision-making on complex, contentious projects such as electric power or water supply systems.

An important class of multiple criteria decision analysis techniques consists of those which seek to optimize multiple objectives. Multi-objective decision-making problems are essentially design problems, in which mathematical programming is used to create a "best" alternative from an extremely large, continuous set of choices, subject to specific design constraints. The multiple, and possibly conflicting objectives of the decision maker must be elicited and quantified, in order to provide a basis for the optimization exercise (Rosenthal, 1985).

Optimizing according to the objective function of the decision maker, subject to explicit constraints, can lead to the formulation of a well-balanced plan. For example, it could guide a water supply decision maker in balancing the relative allocation of resources between new water filtration facilities, lead pipe removal, and extending service to new customers. All of these objectives are desirable, but budget constraints and quality standards may limit the amount of each to be realized.

The decision maker's preferences may be elicited before the analysis, allowing the formulation of an objective function that collapses multiple and conflicting objectives, via weighting schemes, for example, into a single optimizable function (Hwang et al, 1980). This function may include multiple dimensions such as cost, environmental impacts, and quality of service, valued according to the decision maker's preferences rather than the shadow pricing efforts of the analyst. This is a useful approach when the design options are well understood, the decision maker emulates the preferences of his or her constituents, and enough consensus exists to warrant representing peoples' diverse preferences with a single social welfare function.

Conversely, the analyst may generate a large "efficient" set of alternatives, and then later elicit the decision maker's preferences in choosing the "best" of these. Again, this depends upon having already identified the entire "efficient" set, and having a decision maker with a strong public mandate, whose preference mapping is widely shared, and whose decision therefore will not be overturned.

However, information has value in decision-making, and preferences may change over time as new information is received. Thus, for some projects, it may be desirable to elicit the decision maker's objectives in an interactive manner, by repeatedly gauging his or her tradeoff preferences, as new data become available (Hwang et al, 1980). This interactive approach allows new options to be identified, and lets the decision maker incorporate the viewpoints of other interested parties into the objective function, as potential project impacts are revealed.

Uncertainty is typically considered only through sensitivity runs that bracket preferred solutions. The robustness or flexibility of an option in an uncertain future is thus limited to being a second order rather than a primary decision-making criterion. Multi-objective optimization approaches also have the disadvantage of being "black box" methods that provide an optimal solution (or small set of superior solutions), without illustrating clearly to decision makers and the public what tradeoffs were made while winnowing out the inferior options.

Multi-Attribute Decision-Making

A second class of multiple criteria decision analysis techniques is particularly useful when only a limited number of options must be evaluated. The performance of each option can be revealed in an attribute vector that describes, for example, its cost, environmental impacts, and quality of service impacts. Multi-attribute decision-making tools then focus on assisting in the choice process among these existing alternatives, typically using either optimization or sorting methods (Rosenthal, 1985).

The fact that a finite number of alternatives is being evaluated means that some pre-selection must occur. Implicit rather than explicit constraints are employed by the decision maker to screen out infeasible options. This method is thus useful when the option set is well understood, and lumpy enough that hybrid options are unlikely to be created. For example, when the set of water supply options is limited to indivisible "big ticket" items, such as building either a holding reservoir or a storage tank and tower, then multi-attribute analysis may be appropriate.

Inferior options may be weeded out using a general decision rule such as dominance (superior options perform better across all attributes than inferior options), or more refined rules such as maximin or maximax.

In order to sort through the option set, qualitative attributes often must be quantified (although not valued), and normalized to a certain degree. Whether simple ordinal ranking is used, or a more versatile interval or ratio scale is devised, care must be taken to limit the use of the numbers to sorting within individual attributes, rather than aggregating them across attributes. Aggregation requires the additional step of developing a weighting function and ratio scales.

If information on the decision maker's preferences is available, then weights may be attached to attributes prior to the sorting process. The sorting may proceed using additive weights across attributes, or hierarchal systems that focus first on one attribute, and then others (Hwang et al, 1980).

Uncertainty may be addressed in this type of method by simulating the performance of options across a range of possible futures, and then using "inter-future" sorts to identify robust options, i.e., those with lower variance. Robustness may then be included as an additional attribute in the final sorting process.

Interactive uses of multi-attribute analysis have the advantage, as above, of allowing new options to be introduced into the decision set, and of allowing decision makers to enjoy input from concerned parties, as project impacts become revealed. However, most of these techniques retain a "black box" appearance that may hinder acceptance of the results if the project politics are contentious.

Tradeoff Analysis

There is a variant of multi-criteria decision analysis that focuses explicitly on accommodating broad public participation. The tradeoff analysis approach assumes that a group rather than an individual will make the planning decision. It is an especially useful technique when controversy surrounds a project proposal, social consensus on appropriate action does not yet exist, all options have not yet been identified, and uncertainty affects the relative attractiveness of alternative designs. For example, if the water supply agency finds the choice between chlorinating water and removing lead pipe to be controversial, it could set up a citizens' advisory group to explore the tradeoffs between these options. By placing some of the decision-making power in their hands, the decision, once made, may be more stable.

These techniques draw on the strengths of other decision analysis tools. They are designed for interactive applications, in which interested parties evaluate the multi-attribute impacts of project options in an open way that reveals the various tradeoffs implicit in choices among options. The tradeoffs in part are characterized using measures of both an attribute's absolute magnitude and its variability across options (Connors, 1989). Uncertainty is likewise addressed, as above, by examining an option's robustness across possible futures (Schweppe & Merrill, 1987).

Individual members of the decision-making group may be assisted in sorting options, as above, according to their own preferences (Bespolka, 1989). Preferences may change as additional information is provided. Further, new options may be invented by the participants that may be included in the next iteration.

In later stages, consensus-building efforts may (in theory) be assisted by graphical performance profiles, and iterative, pairwise dominance comparisons that help the decision makers to winnow out options universally identified as inferior (Bespolka, 1989). Explicit analysis of the tradeoffs between options could allow compensation packages to be developed addressing the concerns of those who stand to lose something from project implementation (O'Hare et al, 1983). Equity concerns can thus be made an integral part of the analysis and decision-making processes.

This type of approach has the advantage of being "open" as opposed to "black box." All of the participants would know how the favored option was chosen, and of the tradeoffs involved in that choice. Choices would be made directly by them, rather than by a mathematical programming technique that simulates their preferences. The decisions made are thus more likely to meet with public acceptance and approval (to the degree that all stakeholders were represented in the decision-making group).

Tradeoff analysis is time consuming and cumbersome; thus it enjoys limited application. Indeed, most of the sorting and tradeoff analysis tools beyond simple dominance comparisons have never been applied in practice; they have enjoyed only theoretical development. It may not be an appropriate technique when a significant level of public participation will not improve the efficiency, equity, stability, and wisdom of the planning decision. Small, popular projects with few spillovers may not benefit from the extensive amount of public involvement apparently implicit in the tradeoff analysis approach to decision-making.

Scenario-based Multi-attribute Tradeoff Analysis

Better planning processes and analysis tools are needed in today's decision-making environment, given that controversy, complexity, and uncertainty have overwhelmed some planners of large, long-lived, high-impact investments in recent years. This section outlines a scenario-based multi-attribute tradeoff analysis technique designed in this research to satisfy those analysis requirements. The current state of the art in tradeoff analysis, as described above, serves as the foundation upon which my contributions are based.

The elements of this approach have been individually applied to various planning problems, but they have been developed mainly as heuristics, or "techniques that work" in specific planning situations. Scenario analysis, for example, has become popular as a way to avoid the pitfalls of deterministic planning by exploring a small number of alternative sets of possible future events (Destribats & Malley, 1988; SoCal Edison, 1988). Likewise, multi-attribute evaluation has proved useful in cases where valuation and aggregation problems undermine the validity of cost-benefit analysis (Keeney & Raiffa, 1976, pp. 5-30; McAllister, 1982). Tradeoff analysis is gaining popularity for its ability to provide a "paper trail" for open planning efforts (Andrews et al, 1990; Connors, 1989; Bespolka, 1989).

Planners faced with massive uncertainty and controversy have also identified several techniques not to use (recall Chapter Three's questionnaire results). Don't do deterministic planning for a single assumedly-certain future. Don't econometrically extrapolate future events only from what happened in the past. Don't evaluate options without taking their systemic context into account. Don't derive an optimal plan inside of a "black box" that obscures value judgements and assumptions from public scrutiny. Don't put all of your eggs in one technological basket. Don't commit sins of omission; that is, don't ignore plausible alternatives or uncertainty.

Mainstream decision science uses the concept of expected utility to deal with uncertainty. Preferences are assumed to be a function of the value of an outcome, its probability of occurrence, and the decision maker's risk aversion (Keeney & Raiffa, 1976, pp. 6-7). This continuously-differentiable function is conceptually pleasing as a decision rule. However, unless the analysis digs below the probabilities to examine the various pathways leading to a particular outcome, very little will be learned about the behavior of the system under study. Creative thinking about better strategies will not be encouraged unless the decision maker learns something about both his or her preferences and the way the system works.

The tradeoff analysis approach is specifically intended to clarify how a complex system works. Various innovators have developed techniques that offer piecemeal insights. For example, from the first electric power industry application of tradeoff analysis (Luce, 1980) to the present (Connors & Andrews, 1990), scatter plots have been used to evaluate the relative performance of different strategies in multi-attribute space. Another technique is the use of SMARTE (Simulation, Modeling And Regression, and Tradeoff Evaluation) functions, which develop a straightforward functional relationship between uncertainties, options, and impacts (Merrill, Schweppe and White, 1982). These functions (based on least-squares curve-fitting) describe system behavior in a way that clarifies relationships and helps in choosing among options, based on a limited set of simulations. RISKMIN is yet another specialized data-base tool, used for systematically identifying dominant options in a large set of scenarios (EPRI, 1988). These techniques are evidence of the growing consensus that planners ought to explore a variety of possible future circumstances, and systematically analyze many strategies for each set of circumstances.

The shared intuition underlying this consensus is that the best way to begin creating a better future reality is to sample its possibilities in an organized manner. This offers a starting point for crafting a unifying concept to motivate analytic efforts. The essence of that concept is that we should think of the planning process as a formal intellectual investigation of a complex system's behavior based on a limited set of experimental results. By including a rigorous scoping of the experimental design and attention to sample characteristics, quality control, inductive data analysis, and defensible conclusions, we can improve the chances of obtaining meaningful results. Techniques such as scatter plot tradeoff curves, SMARTE functions and RISKMIN are heuristic expressions of what can really be considered a future-sampling approach to systems analysis.

Sampling the Future

Controversy and uncertainty mandate that we look at a large enough range of possible future events to learn something about the behavior of the system, en route to choosing a plan of action. As with any experiment, we want as comprehensive and representative a set of experimental results as possible. But what does this mean when it is the future that is being examined?

When designing experiments to test hypotheses about existing systems, one typically chooses between equalized and controlled experimental conditions (Olson & Picconi, 1983). In our context, the emphasis is on controlled experimental conditions, which require that we hold all conditions constant except for the one factor being studied. To study several different factors we would run a number of controlled experiments.

However, there are an infinite number of factors to control; thus an infinite number of controlled experiments would need to be conducted to be sure of the results. Therefore we need to bound the analytic task contextually.

The number and characteristics of the scenarios analyzed in our "future-sampling" experiments should depend on the audience for the planning effort; the greatest hopes and worst fears of each individual participant must be addressed in the analysis. Within this context, the philosophy of controlled experimental conditions may be maintained by changing one factor at a time between scenarios.

Combinations of specific uncertainties and options that concern the participants can be included in the set of scenarios studied. Without stating a specific number of experiments, we can prefer a large set to a small one, and expect the number to increase as the number of participants in the planning process grows.

A possible future can be defined as the occurrence of a unique combination of independent uncertain events. Uncertainties, or factors over which we have no control, may include economic growth rate, fuel price and availability, weather, and the advent of new technologies, for example. For modeling purposes, a possible future can be defined by the vector of values assigned to these uncertainties. Thus one possible future would have high economic growth, moderate fuel prices, no fuel shortages, normal weather, and on-time availability of new technologies. Another possible future might differ by only one uncertainty value, say, having low economic growth, but all other uncertainty values unchanged. Likewise, a strategy can be defined as a unique combination of options, or factors over which we exert control.

Monte Carlo simulation is one popular method for capturing the effects of uncertainty (NPPC, 1986) that emphasizes equalized instead of controlled experimental conditions. It assumes a probability distribution for possible future events, and then randomly samples from that distribution to get the uncertainty values that drive the modeling effort. By taking enough samples, the modeling effort can be made to enjoy the same distribution of outcomes as the uncertain inputs. This approach is useful when there is a consensus about the range and distribution of possible future events. However, when there is no consensus on the relative likelihood of possible futures, or when discontinuities rather than smooth uncertainty ranges are of interest, then a scenario-based approach may be more appropriate.

For our purposes, there are several reasons why it is better to model discrete possible futures rather than a probabilistic continuum. First, as mentioned above, we learn about the behavior of the system in response to factors (options and uncertainties) that are discretely defined. Second, many people can easily conceptualize specific possible futures comprised of independent uncertainties. Third, different stakeholders can focus their attention on different possible futures -- those of greatest individual interest. Finally, the relative probabilities of these possible futures can be easily changed during subsequent analysis, using either holistic (one possible future relative to another) or component (one uncertainty value relative to another) assignments.

The Importance of Symmetry

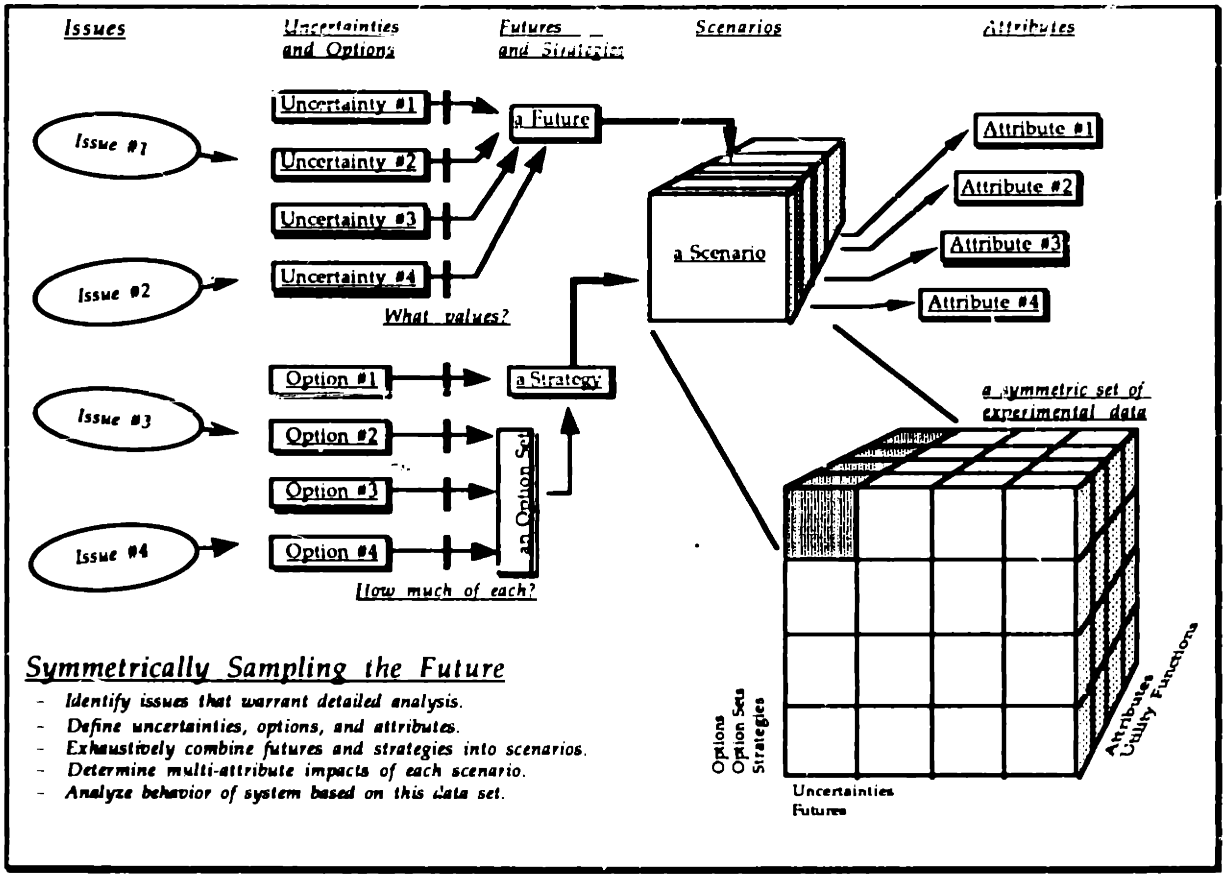
If several factors are of interest when exploring the future, then a large number of controlled experiments, or scenarios will need to be analyzed. People typically think first in terms of uncertainties, and only later about specific possible futures. Thus I perceive it to be valuable to construct symmetric sets of experiments to allow cross-sectional analysis of the data set by uncertainties (see Figure 4-1). This results in large data sets. If, for example, three independent and collectively exhaustive uncertainties were modeled, and each had three possible values (low, medium, high), then the total number of possible futures in the symmetric sample would be 3x3x3 = 27. While this "curse of dimensionality" daunted previous generations of modelers, cheaper computing power is making this approach increasingly feasible.

An additional important justification for symmetry is the fact that assigning probabilities of occurrence to different possible future events is a highly subjective task. If two parties in a controversial planning effort initially disagree on the relative probabilities of different possible futures, then they will not be able to agree on the expected-value results of the analysis either. By initially assigning equal probabilities to all possible futures modeled (with symmetric sampling), normative probability assignments may be postponed to a later stage in the analysis. Asymmetrical sets of experiments have zero probabilities implicitly assigned to certain possible futures.

The other term in the planning equation is the options, or factors over which we exert control. In a complex system the individual options usually must be packaged into combined strategies. Where controversy and uncertainty affect the planning process, it becomes important to explore a wide variety of strategies, both to satisfy the concerns of the various stakeholders, and to understand their relative performance across a range of possible future events. Again, symmetry in constructing the strategies is valuable so that analysis by option can be done.

Individual technological options (a power plant, for example) may be quite small relative to the system in question, and may be combined with each other in a myriad of ways to create a strategy for use in a complex system. Thus it is often useful to consider option sets instead of options as the basic building blocks of the symmetric data set. An option set is a strategic combination of many individual options, i.e., it is a grouping of options while still only a component of a strategy. Option sets help to limit the symmetric data set to a manageable size. Exhaustive cross-sectional analysis can then be done by option set rather than individual option. If each strategy consists of one demand-side option set (of 15 modeled) and one supply option set (of 4 modeled), then the total number of strategies in a symmetric set would be 15x4 = 60.

Figure 4-1: Sampling the Future



Symmetrically Sampling the Future

- *Identify issues that warrant detailed analysis.*
- *Define uncertainties, options, and attributes.*
- *Exhaustively combine futures and strategies into scenarios.*
- *Determine multi-attribute impacts of each scenario.*
- *Analyze behavior of system based on this data set.*

A scenario can be defined as one possible future combined with one strategy. With 27 possible futures and 60 strategies, the total number of scenarios in a symmetric set of experiments would be 27x60 = 1620. Most previous scenario analysis exercises have avoided this emphasis on symmetry because of the large computational burden (SoCal Edison, 1988). Instead, they have analyzed a relatively small number of scenarios for the anecdotal lessons that can be learned. However, as computing time becomes cheaper and data manipulation easier, it makes sense to move beyond anecdotal evidence to a more rigorous approach.

Multi-Attribute Evaluation

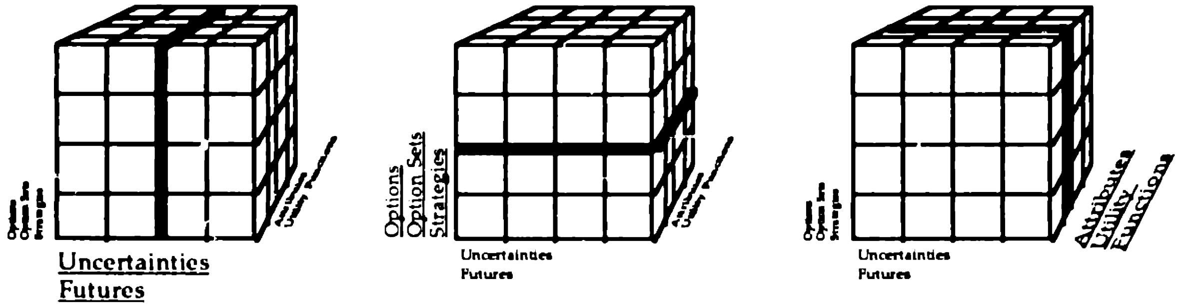
Earlier sections have discussed the value of multi-attribute analysis when planning controversial projects. To review briefly, multi-attribute analysis postpones the difficult task of assigning values, i.e., monetizing the intangible impacts of a project, such as its environmental impacts, by carrying impacts forward in their original units, whether dollars or tons of SO_2. This approach reduces the subjective content of the initial stages of the analytic effort, and allows the intermediate results to remain useful to more of the stakeholders. Since different parties care more about some attributes than others, this approach allows them to quickly rank options according to their own preferences based on performance along their favorite attribute(s). Multi-attribute evaluation also assists parties in understanding the behavior of the system, and in identifying the characteristics of dominant strategies.

The Implications of this Approach

A large, symmetric set of scenarios represents an experimental "sample of the future" that warrants detailed statistical analysis. While we cannot develop confidence intervals relating the sample to what the actual future holds, we can develop sample statistics that teach us a great deal about the performance of our options (and strategies) within a complex system, as well as the effects of uncertainty on that system. Thus we use controlled-conditions experimental design philosophy to create a large number of distinct scenarios, but then apply the equalized-conditions philosophy to the symmetric set of scenarios, our "sample of the future."

Standard statistical techniques may be fruitfully applied to this sample: sample means, variances, maxima, minima, correlations, regression analysis, histograms, box plots, and scatter plots are all useful for detecting patterns in the behavior of the system. Cross-sectional analysis by option set, strategy, uncertainty, possible future, single attribute, and functional representations of multiple attributes are particularly helpful for understanding the performance of individual option sets, the impacts of specific uncertainties, and significance of stakeholders' preferences (see Figure 4-2).

Figure 4-2: Analyzing a Symmetric Data Set

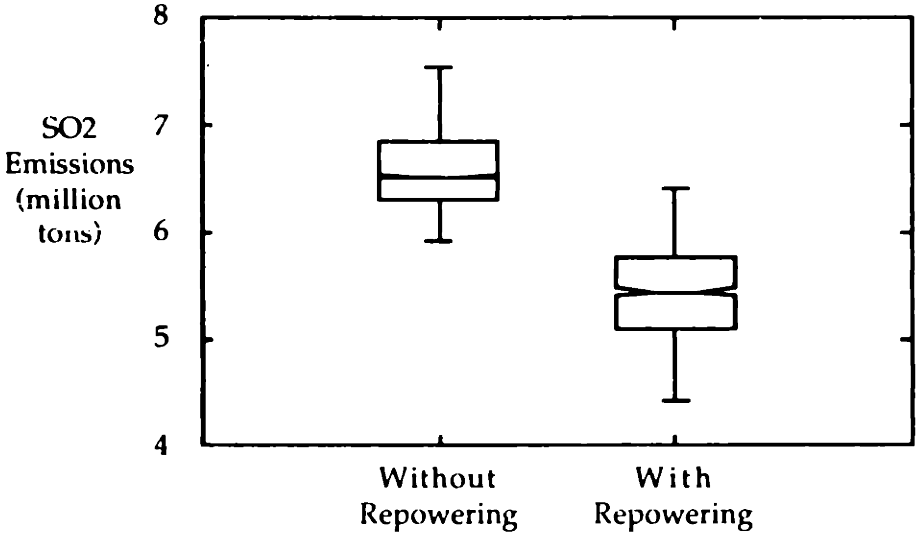


The techniques mentioned earlier -- scatter plot tradeoff curves, SMARTE functions, and RISKMIN, can be viewed as piecemeal applications of selected statistical tools to an experimental data set consisting of samples of the future. By recognizing this, we reduce the need for specialized data analysis software: standard statistical packages will do much of the data reduction work. For example, the pair of box plots in Figure 4-3 below, in which a New England data set of 2160 scenarios was divided into two cohorts

– with and without repowering of existing power plants – shows that this option can make a dramatic difference in SO_2 emissions over a range of experimental conditions.

The programming challenge lies in integrating models of subsystems to allow rapid evaluations of large numbers of scenarios. The analytic challenge becomes one of developing an efficient, effective strategy for mining the data amassed during the multi-attribute scenario simulations. There are several factors to consider. First, it may be necessary to present the results in a variety of different ways, depending on the interests and expertise of the audience. While an expert audience may be willing to wade through dozens of box-and-whisker plots to understand the precise influence of an uncertainty on system behavior, a lay audience will only be interested knowing the general direction and magnitude of that influence.

Figure 4-3: Range of Sulfur Dioxide Emissions with and without Repowering
(1080 Scenarios for each case)



Second, understanding the behavior of the system is more important during the process of inventing strategies than it is when a final choice among strategies must be made. The creative process is expansive: the initial focus of the brainstorming is informed by data showing the characteristics of different options, which then suggests improved strategies to target in subsequent analysis. The choosing process is directional: unsatisfactory strategies are eliminated and a small decision set is slowly winnowed down to a preferred choice. The selection of analytic tools should change in different phases of the process.

Finally, the analysis must make the best reasonable use of the limited experimental sample, and no more. It is unrealistic to expect to answer every question about the system's behavior, or to study every conceivable option in one iteration of analysis. A series of limited, but timely experimental data sets will provide information more efficiently than a single, long-awaited mega-sample.

An important advantage of this approach, based as it is on the creation of large, symmetric data sets, is that the relative "robustness" of options and strategies may be quantitatively measured (in terms of sample variances). Previous tradeoff techniques worked with -- at best -- vague definitions of this concept based on visual inspection of the movements of strategies on scatter plots, or counts of cases of dominance across futures.

A question that is often asked by experienced negotiators when initially introduced to this approach is: "Why not just do joint model-building, and thus avoid having to run so many scenarios?" Four points summarize my response. First, this approach does have elements of joint model-building, in the sense that many joint assumptions are made in building the modeling "engine" that produces the scenario results. Second, the presence of uncertainty mandates that a wide variety of cases be examined. Third, creative thinking, or brainstorming, generates many options that deserve to be explored. Finally, either new information or turnover in the planning group can cause parties to revise their assumptions about the probabilities of future events.

How "Smart" Should Scenarios Be?

Models of complex systems have numerous feedback loops, wherein electricity demand is partially determined by its price even as the price is in part a function of demand, for example. Choosing which feedback loops to close within each scenario, and which to leave open, is an important decision in our context. In other words, which factors should be made endogenous and which should be left exogenous; how "smart" should we make the scenarios? This decision depends on several factors which are discussed below, and illustrated in Figure 4-4.

First, which feedback loops are we capable of modeling? Linkages may exist but be impossible to model with the analytic resources available. For example, while we can hypothesize a link between regional utility sulfur dioxide emissions and regional economic growth, based on the effects of acid rain on regional agricultural and forest products industries, that link would be difficult to model. We would have to simulate the: (1) emissions rates and quantities from utility sources, (2) geographic dispersion of the pollutant from each source, (3) effect on ambient pollution levels at different points in the region, (4) deposition of the pollutant on economically productive farm and forest land, (5) absorption/ingestion of it by different types of plants, (6) adverse influences on crop growth resulting from the marginal pollution increase, (7) effects on agricultural/forest yield, (8) effects on harvesters' revenues, and finally the (9) effect on remainder of regional economy from these losses. Each of these steps requires the modeling of one or more complex subsystems -- electric power systems, weather patterns, agricultural productivity, the economy -- any one of which could claim all of a project's analytic resources. The project budget thus may dictate that we break this feedback loop, and consider sulfur dioxide emissions an output of the model (as in Figure 4-4 Point A).

Second, which feedback loops involve too many uncertainties for us to model effectively? This is a direct extension of the first point. If we cannot develop complete models of each of the sub-systems mentioned in the example above, then we will not be able to get self-consistent results. In some cases, such as the behavior of commercial building owners regarding conservation investments (Jackson, 1988), it is quite reasonable to assume that a probability distribution of acceptable paybacks may be used to drive a closed-loop, within-scenario Monte Carlo simulation. However, when modeling the growth in demand for electric services, events such as changes in regional weather or economic patterns may invalidate any simplifying assumptions we were forced to make to reduce the feedback relationship between this year's and next year's demand to a manageable form. In such a case it would be better to break the feedback loop and acknowledge the uncertainty (as in Figure 4-4 Point A).

Third, which feedback relationships are significant enough to bother with? The sulfur dioxide emissions/economic growth example above is also likely to fail under this criterion. Since most (90%) of the region's ambient sulfur dioxide blows over from states to our west, while most of our utility emissions migrate eastward, and a large share of locally produced SO_2 derives from non-utility sources anyway, it is likely that this interaction is less valuable to measure than other types of feedback.

Fourth, which linkages involve evaluating intangible impacts that may be controversial? For example, there are a variety of non-agricultural impacts of sulfur dioxide emissions on the economy, including damage to exterior structures and monuments, and health effects on animals and people. Describing these impacts in economic terms involves placing dollar values on the historic significance of buildings and monuments, and on human lives. The different parties in a planning debate are unlikely to agree on precise values to place on such intangible assets. At best, a range of values will have to be analyzed, which implies breaking the within-scenario feedback loop and running multiple scenarios (as in Figure 4-4 Point B). Where assumptions are not unanimously endorsed, multiple scenarios must be run.

Fifth, are the linkages themselves (or their importance) controversial? If so, then a range of scenarios will again have to be explored (as in Figure 4-4 Point B). A classic example of this is the "Khazzoom effect," which is posited to reduce the effectiveness of mandated appliance efficiency improvements because, as customers' utility bills decrease with help from more efficient appliances, and their disposable income increases, this encourages more profligate energy use because energy is a good that people want more of if they can afford it (Khazzoom, 1980). Many economists and conservation advocates claim that this effect does not exist to any significant extent in the utility context (Goldstein and Watson, 1986).

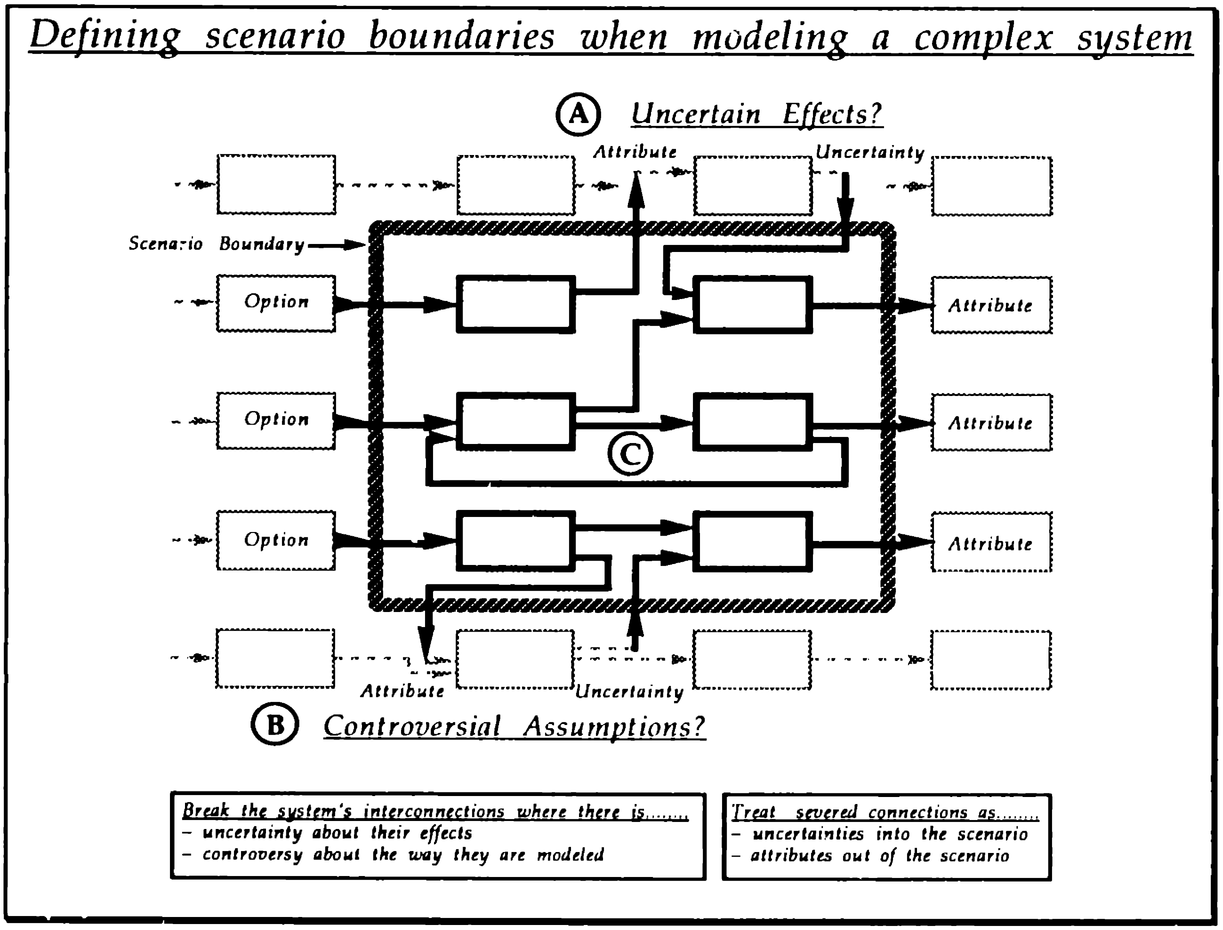
Sixth, when modeling scenarios that unfold over time, such as the 20 year study frame of the New England project, what does the audience most want to hear about - technical strategies or decision rules? If the parties are most interested in understanding the impacts of a particular technological emphasis, then the year-to-year planning loops must draw exclusively upon the technical options that comprise that strategy. In contrast, if the group is more interested in learning about the impacts of a decision rule, such as "plan for least investment risk," then a large menu of technical options must be available to select from every year of the planning period. Any multi-period scenario analysis is de facto a combination of these two extremes, having either a larger or smaller set of options from which to choose each period, using a more or less stylized decision rule.

Finally, which model boundaries contain the range of perspectives of the parties involved? The boundaries of the system being studied depend a great deal on the interests of the participants in the planning process. A regional planning project, for example, is likely to define national economic growth as an exogenous variable, because none of the parties involved has any macroeconomic leverage. Extra-regional impacts (such as the global warming contribution of local CO_2 emissions) are likely to be of interest, but feedbacks from those effects are not.

None of these points precludes the use of systems dynamics models for the simulations. However, they suggest that individual iterations across ranges of uncertain or controversial factors may need to be reported as distinct scenarios.

In summary, the "smartness" of the scenarios depends on two kinds of context: analytic resources and stakeholder perspective. Feedback loops that contain uncertain or controversial factors need to be cut at the scenario boundary (see Figure 4-4 Points A and B). Loops that are deterministic and have unanimously acceptable assumptions may be closed when modeling each scenario (see Figure 4-4 Point C).

Figure 4-4: Defining Scenario Boundaries



Procedural Framework

A proven consensus-building process for resolving public disputes was outlined in Chapter Three. Several of the steps commonly found in successful negotiating processes may benefit from analytical support. An open planning process needs to go one step further, and incorporate consensus-building steps into a traditional planning process. The overall planning process may be defined to consist of several conceptually discrete (but actually interactive) steps. Goal definition is Mayer and Greenwood's (1980) suggested starting point; it may be followed by needs analysis, statement of objectives, developing project alternatives, choosing among alternatives, detailed project design, implementation, evaluation, and feedback.

Recent contributions to the state-of-the-art of tradeoff analysis only recognize the relevance of parts of the type of process outlined in Chapter Three. Connors (1989, p. 21) notes that several of the activities listed therein are likely to improve the outcomes of planning in an "open-decision environment," and that the strengths of tradeoff analysis complement the modeling needs of such a process. However, he stops short of tying specific analytical tasks to specific steps in this process. Bespolka (1989, p. 84) develops a detailed framework for performing tradeoff analysis that defines both the goals and timing of interactions between analysts and negotiators. However, his framework imperfectly matches the needs of a consensus-building process with the proposed analytical tasks; at one point suggesting activities that could disrupt a negotiation (a priori preference elicitation), while ignoring another crucial step (inventing options). It also focuses on the analytical task confronting a single generic stakeholder, without addressing the interactive needs (among stakeholders, and with the developer) of a consensus-building process.

The framework discussed below matches analytic tasks with process steps. I suggest that the joint fact-finding effort be organized so that four steps carry the group through a full cycle (Andrews et al, 1990; Connors et al, 1989), with a final goal of consensus. These steps are shown in Table 4-1, and brief discussion of each follows. Full details of the approach are best illustrated with an actual example. They are thus included with the case study described in Chapters Five, Six and Seven. Note that this is the initial structure, developed for testing in actual planning experiments. A revised structure incorporating the lessons learned in the experiments described in Chapters Five through Eight is presented in Chapter Nine.

Table 4-1: Open Planning Process Steps (Initial Framework)

1. **Identify issues** to focus the analysis upon, **and attributes** by which to compare the performance of different options.

2. **Develop scenarios** examining the performance of combinations of options (strategies) across a variety of uncertain future events (futures).

3. **Explore system behavior** by observing the multiple-attribute tradeoffs between strategies, for a variety of possible uncertain future conditions. Develop better strategies based on this information.

4. **Understand participants' preferences** by observing which strategies interest each party, what uncertainties concern them, and how they weigh the various attributes relative to one another. Develop strategies with the potential for consensus based on this information.

Repeat........

5. **Seek consensus** on a favored strategy.

Step One: Identify Issues and Attributes (Initial Framework)

An open planning effort should begin by focusing on agenda setting, representation, and similar structural concerns. Once an analysis team has been selected or volunteered, the joint fact-finding work may begin. The analysts have important tasks that are distinct from, but complementary to those of the open planning group. They are responsible for helping the conveners articulate the goals driving the project and understanding the stakeholders' positions.

The analysts should also provide examples of issues and attributes to facilitate discussions at the first meeting of the group. These should consist of items that are likely to be interesting to both the participants and other parties not yet represented in the group. As additional issues are raised, less relevant ones may be postponed, and a consensus prioritization should be sought. A confidential follow-up questionnaire will allow participants time to confirm their preferences with their constituents, and freedom to express views either overlooked or too controversial to raise in the meeting. Based on the discussions and the questionnaire responses, they should settle on a set of primary issues around which to focus the initial analytic effort, accompanied by a limited number of attributes for measuring the performance of options.

An important analytic task during this phase of the process will be thinking on behalf of the various stakeholders, to make sure that both their voiced and unvoiced concerns are addressed. A balance should be sought on the set of issues that gets examined.

The left side of Table 4-2 shows the steps in an open planning process that includes elements of a consensus-building process embedded in an overall planning framework. The right side describes the analytical tasks accompanying each step, indicating whether participation by all of the stakeholders is required, or only the developer. More details on the activities shown in the table are provided in the case studies (see Chapters Five through Eight).

Table 4-2: Step One – Initial Analytic and Procedural Framework

Open Planning Process Step	Analytic Task & Technique	
	All Stakeholders	Analysts & Developer Only
1.a. Define Goals		Articulate goals driving project
1.b. Analyze Need		Internally identify need for project Assess BATNA
1.c. Launch Open Planning Exercise Representation	Assess BATNA s More participants	Stakeholder analysis
1.d. Statement of Objectives	Elicit issues related to project objectives Prioritize issues Elicit attributes	Cluster the issues

Step Two: Develop Scenarios (Initial Framework)

The issues are translated into analyzable form by defining scenarios. These scenarios are comprised of the options available for addressing the issues, and the uncertainties surrounding their performance. As was mentioned earlier, a strategy (comprised of supply and demand option sets) is combined with a future (one combination of possible events) to define a scenario. Scenario analysis allows us to evaluate the performance of different strategies across a variety of uncertain futures, where all futures are initially assumed to have an equal probability of occurring. Of course, scenario analysis requires many computer runs (N strategies times M futures), so that the stakeholders must decide together how to prioritize scenarios to accommodate constraints imposed by limited computing resources. Higher priority strategies and futures should be run first, others can be included in subsequent iterations of the process.

The modeling techniques used to evaluate the scenarios must do an adequate job of simulating the system's performance, in the eyes of all participants. Validation using historical data, and checking of intermediate results with expert members of the group will build confidence in the final product. Within Step Two, the procedural and analytic tasks are structured as shown in Table 4-3.

As was mentioned earlier, the range of futures modeled should include not only those of special interest to different parties, but also those needed to ensure a symmetric, or balanced experimental sample. This will allow cross-sectional analysis of the resulting data base, and permit changes in probability assignments by both uncertainty and future.

Table 4-3: Step Two – Initial Analytic and Procedural Framework

Open Planning Process Step	Analytic Task & Technique	
	All Stakeholders	Analysts & Developer Only
2.a Joint Fact-Finding		
Specify information gaps	Specify need	Develop data
Locally unknown information	"	"
Historical information	"	"
Generally unknown information	"	"
Uncertainties, i.e., unknowable info	"	"
Validate information obtained	Validate data	Document sources
Background data	"	"
Assumptions	"	"
Uncertainty ranges	"	"
	Prioritize uncertainties	
Exogenous constraints	Validate data	Document sources
Modeling techniques	Validate results	Do test runs
2.b. Define Plausible Futures (uncertainty sets)		
Define "high-interest" futures	Specify these	Quantitatively define futures
Define "balanced sample" blanketing range of uncertainty values	Validate coherence	Quantitatively define futures Ensure symmetry
2.c. Develop Project Alternatives	Brainstorm for options	"Plant" favored options Include extremes in order to provide "landmarks" for group Quantitatively define options Combine individual options into planning strategies (option sets)
	Validate definitions	Ensure symmetry
	Prioritize scenarios for the analysis	
2.d. Determine Impacts of Strategies		Run models & develop multi-attribute decision matrix for strategies across futures Eliminate infeasible strategies based on exogenous constraints
	Validate modeling results	

Symmetrical construction of strategies will likewise enable cross-sectional analysis of the data base. Strategies of particular interest to the developer may be "planted" in a larger data set, to gauge public reactions to an idea before it is formally proposed. Extreme strategies, such "No Conservation" or "All Gas-fired New Capacity" are useful to include because they serve as landmarks to which the group may relate the more realistic intermediate strategies.

There will often be a need to fill information gaps during the scenario development process. Locally unknown information, such as unit costs of appliance efficiency improvements, must be obtained from outside sources. Historical information, such as past electricity prices, may need to be presented to provide a context for the planning effort. Generally unknown information, and uncertain information, such as the effectiveness of appliance efficiency standards, or future fuel price levels, must either be assigned an assumed value by group consensus, or made an uncertainty in the analysis.

If exogenous constraints exist regarding the use of options or the levels of attributes permitted, then these must be identified. For example, if a fuel-use act (such as USPL 95-620, of 1978) limits the amount of gas- and oil-fired capacity that may be brought on-line, or if regional sulfur dioxide emissions caps apply, then these must constrain the analysis.

Step Three: Explore System Behavior (Initial Framework)

The multiple-attribute results of the scenario analysis must be systematically evaluated in a way that provides useful (and comprehensible) information to the participants, in spite of controversy and uncertainty. This sample of possible futures can be attacked with any part of the arsenal of the applied statistician. Indeed, it is useful in practice to apply an array of those tools to the data set. In doing so, it is helpful to remember that there are three primary goals of tradeoff analysis: to develop a shared understanding of the tradeoffs involved in different choices, to invent better strategies than are currently on the table, and to seek an informed consensus on a course of action. Unlike other techniques aimed only at facilitating choices, this approach has a parallel goal of learning more about the behavior of the system.

Table 4-4: Step Three – Initial Analytic and Procedural Framework

Open Planning Process Step	Analytic Task & Technique	
	All Stakeholders	Analysts & Developer Only
3.a Observe the Effects of Uncertainty	Review results	Perform inductive data analysis
3.b. Observe Univariate Performance of Strategies	Review results	Perform inductive data analysis
3.c. Observe Multivariate Performance of Strategies	Review results	Perform inductive data analysis
3.d. Observe Performance of System	Review results	Perform inductive data analysis
3.e. Invent Better Strategies and Identify More Relevant Uncertainties	Brainstorm	Summarize trends

The joint fact-finding exercise outlined in Table 4-4 above will allow the participants to move through the third step in the open planning process, and invent a better class of strategies.

Step Four: Understand Participants' Preferences (Initial Framework)

The tradeoff analysis approach allows the group to first explore the relative performance of different strategies without initially attaching dollar values to such intangible items as pollution impacts. Unlike cost-benefit analysis, which requires such "social costs" to be valued in dollar terms, tradeoff analysis keeps impacts in their original units (tons of SO_2, for example). This allows parties with very different perspectives to evaluate many of the relative characteristics of the proposed strategies, and encourages their creativity in inventing new options and strategies. By the time parties get down to hard bargaining on the relative importance of electricity costs, environmental impacts, and reliability levels, they will be choosing among a much better set of options. They are also more likely, as a group, to have a better understanding of the relative importance of each issue in the "big picture." The steps included in the preference elicitation phase of the planning process are listed in Table 4-5 below.

This type of analysis helps to focus the discussion on a small "decision set" of strategies that are worth negotiating over. To aid in the process of collective decision making, the strategies are sorted in a variety of ways to reveal their behavior across attributes and uncertainties. Initial sorts are made as "value-free" as possible so that they will have meaning for all stakeholders. Normative content is slowly added to subsequent sorts, first through the use of "generic value-laden sorts," and then with stakeholder-specific sorts.

Uncertainty is both a cause and a result of conflict. Since different stakeholders view the resulting risks differently, the analyst should be able to take different stakeholders' perspectives. The approach presented above acknowledges the stakeholder-specific impacts of uncertainty, and of alternative risk management strategies, by incorporating uncertainties into the utility assessments. This set of activities allows the group to accomplish the tasks outlined in Step Four of the approach (see Table 4-5).

Table 4-5: Step Four – Initial Analytic and Procedural Framework

Open Planning Process Step	Analytic Task & Technique	
	All Stakeholders	Analysts & Developer Only
4.a. Sort Through the Strategies – Slowly Add Normative Content to the Decision Rules		
		Perform analysis
	Review results	
4.b. Elicit Stakeholder Values		
		Develop questionnaire
	Fill out questionnaire	
4.c. Undertake Conflict Analysis		
		Perform analysis
	Review results	
4.d. Invent Better Strategies		
		Summarize trends
	Brainstorm	
Repeat Analysis Steps Above to Determine Whether Consensus Can Form Around a Strategy		
Iterate Until Consensus is Reached, or Negotiations Are Broken Off		

The different perspectives of the parties about possible future events, as well as their preferences among attributes, are easy to accommodate within this analysis framework because of the symmetrical construction of the data set. Information about the relative performance of the strategies may be tailored to the individual participants. The tradeoff curve, or production possibility frontier for a set of strategies, may show that the decision set is quite similar in both of the futures studied. Overlaying the utility functions of two classes of participants, say – cost- and pollution-minimizers – on their respective high-probability futures may show that there is the potential for consensus on some strategies appearing in both decision sets near the point where the indifference maps are tangent to the Pareto-frontier. The characteristics of that strategy may suggest a fruitful path to follow in seeking consensus.

By showing that certain strategies never approach the Pareto-frontier across the range of futures (and attributes) that interest the parties, a shared understanding of the merits of the strategies can develop. Consistently-dominated strategies may be discarded from further discussion, and attention can be focused on the characteristics of the dominant strategies.

Step Five: Seek Consensus (Initial Framework)

Along with joint fact-finding in order to improve the quality of the strategies being debated, there is a corollary goal of developing a more closely shared view among the stakeholders about what to do. The technique is thus designed to be consensus-seeking, although, in this application the participants consider this more of an ideal goal than an actual objective.

A realized planning consensus would require several steps, including producing a written agreement that covers contingencies, binding parties to their commitments, ratification, linking this agreement to formal decision making mechanisms, monitoring, and providing an avenue for renegotiation should events so dictate (Susskind and Cruikshank, 1987) (see Table 4-6).

The multi-step planning process described in this chapter was designed to overcome the barriers of controversy, uncertainty, and complexity, and thereby prevent paralysis in the implementation of large, high impact projects. The next chapter describes the application of scenario-based multi-attribute tradeoff analysis to a regional experiment in open planning for New England's electric power sector. This case study illustrates the working details of the proposed planning process.

Table 4-6: Step Five – Initial Analytic and Procedural Framework

Open Planning Process Step	Analytic Task & Technique	
	All Stakeholders	Analysts & Developer Only
5.a. Choose Among Alternatives		
Evaluate Acceptability of Consensus Strategy to Developer		If adequately attractive, proceed with project
Seek Written Agreement on Consensus Strategy		Write draft text
	Modify text	
	Sign Agreement	
Approval		Present signed text as evidence of consensus
5.b. Detailed Project Design		By Developer
5.c. Implementation		"
5.d. Evaluation	By interested parties	"
5.e. Feedback	"	"

5. APPLICATION TO THE NEW ENGLAND PROJECT: BACKGROUND AND INITIAL STEPS

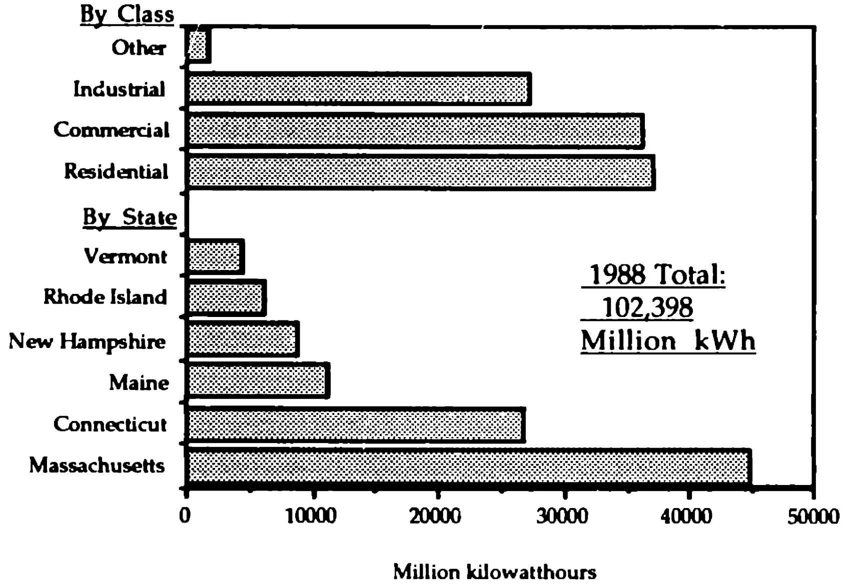
Several practical experiments with collaborative, negotiated, and open planning processes have taken place in New England's electric power industry. This chapter first provides background data to suggest what prompted these efforts, and then describes the details of one experiment, within which most of my research took place. Discussion of the project's background includes a review of the general New England electric power planning context, the current situation, a stakeholder analysis, and recent positive developments, culminating in the inception of the New England project. The New England application of Step One in the open planning framework – Identifying Issues and Attributes – is then presented. The story of Step Two – Developing Scenarios – follows next. The chapter closes with a discussion of the efficacy of these two steps in the New England context.

Background Information

The New England region has a distinctive physical, economic and political landscape. This old, densely populated region hosted the birth of the industrial revolution in America, and its myriad towns and villages have grown into a tightly interconnected megalopolis. The building stock and infrastructure are the oldest in the nation, and are increasingly inadequate for the needs of the current population. Yet, in many areas, there is very little room available for expanding these services. The politically active population challenges all encroachments on the crowded local landscape.

New England is comprised of some of the smallest states in the nation. Indeed, the political jurisdictions are, in many cases, smaller than the electric company service territories. Most of the electricity in the region (90%) is generated by private, investor-owned companies (NEPOOL, 1984). The region's major electric utilities thus face regulation by two or more states, as well as Federal Energy Regulatory Commission (FERC) oversight of interstate, but intra-firm power flows. New England Electric, for example, operates retail companies in three states, and 77% of its revenues come from FERC-regulated intra-firm power sales (NEES 1988). The regional power pool, NEPOOL, offers true economies of scale to its member utilities by dispatching the various power plants more economically, to accommodate regional rather than utility-specific minute-by-minute electricity demands (see Figure 5-1 for a breakdown of usage).

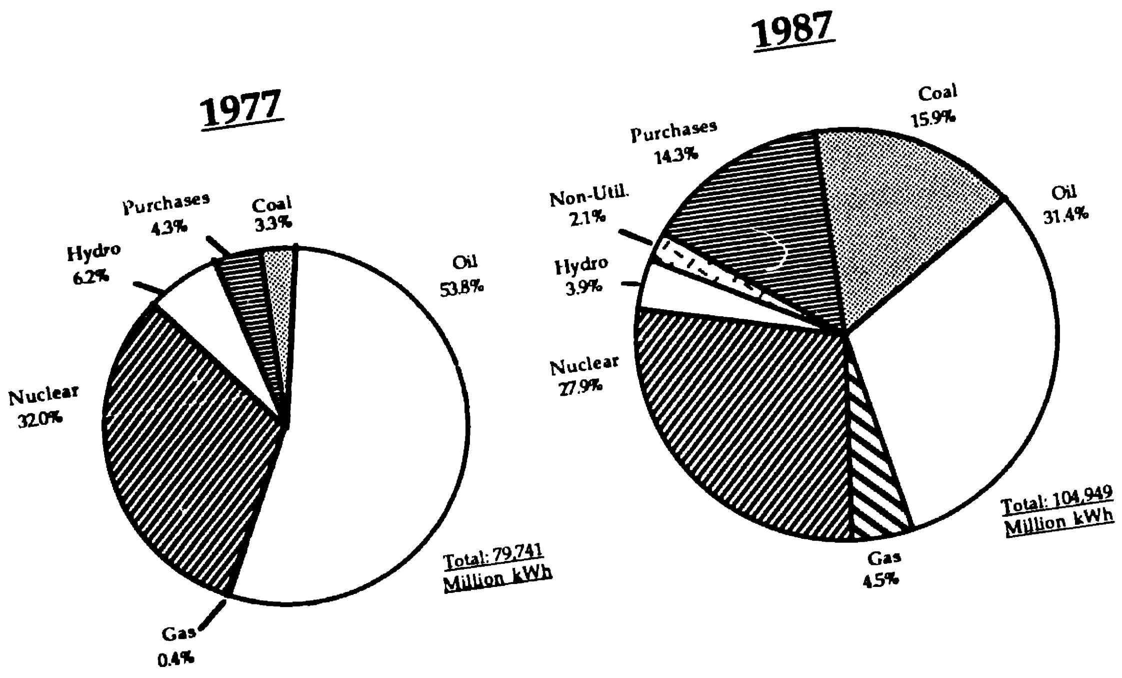
Figure 5-1: New England Electricity Sales in 1988
Source: EIA (1990)



The region has experienced both an economic bust and a boom within the last 15 years. During the slump of the 1970s, the electric utilities, having ordered a large number of power plants during the previous boom period, were left with expensive excess capacity, as unneeded plants finished construction and came on line. Conversely, because few new plants were ordered during the 1970s, the boom years of the 1980s were marked by dramatically decreasing reserve margins between the supply of and demand for electric power (see Figure 1-1, Chapter 1).

With indigenous resources (mainly hydro) providing less than 6% of the power consumed in New England, the region relies heavily upon energy imports (NEPOOL, 1989). Compared with the rest of the nation, it has acquired an atypical generation mix, depending relatively more heavily upon oil, nuclear power, and imported electricity. It also has used relatively less coal, and until recently, less natural gas for electric power generation (see Figure 5-2).

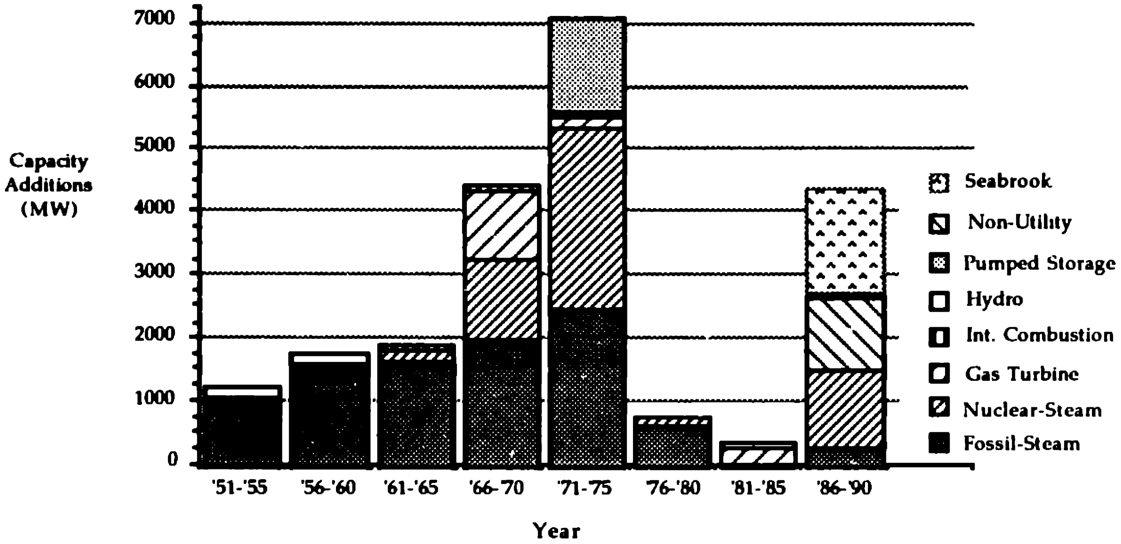
Figure 5-2: New England Generation Mix by Fuel (1977, 1987)
Source: Based on AGREA (1989d), ECNE (1988)



The Current Situation in New England

A serious imbalance between electric supply and demand developed in the region during the last decade. The economic boom of the 1980s encouraged demand to increase at a rapid (and sustained) rate, while, at the same time, very few new supplies came on line to meet that demand (see Figure 5-3). During the late eighties, there were crises during peak demand periods, such as hot summer days and cold winter nights. These indicated that the margin of safety between what could be supplied, and what was demanded, was uncomfortably thin. Figure 1-1 (in the first chapter) shows the number of times that NEPOOL had to invoke an emergency operating procedure, voltage reductions, during each of several recent years.

Figure 5-3: New England Capacity Additions (1951-1990)
Source: Based on AGREA (1989d), ECNE and NEPOOL CELT (1988)



Emergency operating procedures can impose significant costs when invoked. The impacts vary widely from customer to customer (0 - 1.50 $/kWh residential, 1 - 7 $/kWh industrial, per Andersson & Taylor, 1986). Planned interruptions can decrease labor productivity and reduce sales revenues for some firms, while inconveniencing residential customers. Unplanned outages can cause more serious losses, ranging from lost computer data, damaged production, vandalism and looting, to the possible loss of human life. Voltage reductions destroy motors in industrial equipment, air conditioning and heating systems, elevators, and other uses. Recurring outages add to the cost of doing business by forcing firms to invest in backup power supplies; it may even encourage business flight from the region.

A survey of Massachusetts businesses after the 1988 summer heat wave found that a majority had suffered from some sort of outage (Chamber of Commerce, 1988a). Adjusting data from this random sample of 103 Massachusetts firms, I found the following breakdown of electricity outage incidents:

38% -- at least one complete power loss without warning
10% -- at least one voltage reduction without warning
20% -- at least one shut-down or volt. red. with warning
32% -- no problems

I have corrected the Chamber of Commerce estimate of the (monetary) damages to Massachusetts businesses to account for the fact that many of these incidents were due to distribution rather than generation problems. Direct, generation problem-related business losses appear to have exceeded ten million dollars in Massachusetts alone in 1988. While this is not a large sum in comparison to the gross state product (≈0.01%), it demonstrates our very real dependence on reliable electricity supplies. Impressions shared by the respondents with the Chamber of Commerce survey team help us to understand the impacts in personal terms.

> Power loss without warning -- "Power is out NOW since about 2:30 pm!! [interviewed at 4:45 pm] Everything crashed, the computers are out and a motor has burned out. This happens 2 to 3 times per year. There is possible food spoilage, (and) we have no way to verify records. We have to depend on the honesty of the employees. There is potential lost good will, opportunity cost, direct loss of revenue; impulse business. (Equipment damage alone is) $2000." -- Seaside Restaurant, Boston, MA.
>
> Voltage reduction without warning -- "(We have) an average of about 12 per year. (There's a) drop in voltage, the lights flicker, and (it) kicks off a safety switch on the ovens and they shut down. (The result is) we produce materials that are no good. It's a foam rubber insulation; the product is damaged and useless. (Financial impact is) $2000 per drop in voltage; $25,000 to $30,000 a year lost in production and product." -- Armstrong World Industries, Inc., Braintree, MA.
>
> Outage with warning -- "Boston Edison called to warn (us) of a reduction. Bunker Hill decided to close down and send everyone home. (We're) glad they told us or it would have been disastrous for the computers. We closed down, lost income from prospective registrations, and had to make up the work during a hectic time of our fiscal year." -- Bunker Hill Community College, Charlestown, MA.

Why did this apparently unsatisfactory situation develop? Most people agreed that reliable, reasonably priced electricity was a good thing. However, they differed on how supply and demand should be equilibrated.

Stakeholder Analysis

Utilities: Until recently, most of the electric utilities approached the problem with a traditional supply-side mind-set. They favored building new generating capacity in order to meet the burgeoning demand. They did so because: (1) that was what they knew best, (2) they believed that was the least risky, most forward looking way to balance supply and demand, (3) much of New England's generating capacity was quite old, and new plants could be justified on efficiency grounds alone, and (4) their stockholders could earn better rates of return from capital-intensive power plant investments than from alternative activities.

However, the utilities also saw this supply-side approach as an extremely risky financial proposition, for three reasons. First, the state DPUs had refused to allow certain recent supply-side expenditures to be rate-based, on the grounds that they were imprudently incurred. For example, the Massachusetts DPU permitted Northeast Utilities to include only 76% of the cost of the Millstone III power plant in their rate base, and even that was added in increments over several years, to prevent rate shock (NEPLAN, 1988). Second, public (and governmental) opposition to their technology of choice, nuclear, delayed or halted the largest supply-side projects in the region, i.e., Seabrook I and II, and the Pilgrim rehabilitation. Third, they met with stiff local opposition to the siting of other generation and transmission projects, such as the Hydro Quebec tie-line (and now the Champlain gas pipeline) through Vermont.

Expensive project delays, and the possibility that utilities would be denied a return on capital invested, markedly increased the risks of supply-side investments. Thus, many of the utilities were reluctant to make further supply-side investments in the face of such regulatory scrutiny and public opposition (Henderson et al, 1988, p. 7-8).

Some utilities, such as Boston Edison and Public Service of New Hampshire, sought to finish existing supply-side projects. Others, such as Northeast Utilities and Central Maine Power, emphasized an approach with fewer financial risks -- contracting for new capacity with independent power producers. Still others, including New England Electric and Commonwealth Electric, chose a low-risk, low-return approach emphasizing demand-side management activities and purchases of (often imported) power. Neither of these expenditures initially could be included in the rate base, which would have allowed them to earn a return on the investment; instead they were only expensed, i.e., passed through to the customer as an operating expense. These firms all perceived that political viability had become an important project planning criterion, one that was difficult to capture in the private cost-benefit techniques commonly used by their planners. The consensus among the electric utilities was simply that new capacity plans were untenable in the current political and regulatory environment, even if they represented the best approach. Therefore, they waited, seeking change.

Business: Business interests, another fairly monolithic stakeholder group that (on this issue) included organized labor, wanted to maintain the "Massachusetts miracle" phenomenon, and ensure that no obstacles to continued economic growth appeared. They were (and are) more concerned about electricity's reliability than its price. They also worried about being forced by events into a capital-intensive business they knew nothing about -- power production via self-generation or cogeneration.

Like the utilities, most business leaders preferred (utility) supply-side projects, because those allowed room for continued growth, and seemed to offer the surest potential for construction jobs. However, unlike the utilities, they felt that these efforts could not wait for the regulatory and political climate to change, and for regulation-related financial risks to be reduced.

Therefore, they actively worked to change the decision making environment. For example, the Federal Reserve Bank of Boston published a study detailing New England's burgeoning electricity requirements

(Henderson et al, 1988), and the Greater Boston Chamber of Commerce commissioned surveys of outage impacts and business leaders' impressions, plus publishing a quarterly newsletter on energy issues prior to the anti-nuclear Proposition 4 vote (1988a,b & c). An issue-oriented group promoting Seabrook, the Coalition for Reliable Energy, organized forums featuring bankers, lawyers, manufacturers, labor leaders and academics, titled "Find out how today's energy crisis affects you" (Boston Globe, 1988c). Individual leaders spoke out on a regular basis, complaining that "the Massachusetts economy is in jeopardy as the [electricity] crisis grows," and "without adequate power, industry will leave this area or curtail production" (Boston Globe, 1988b).

Other electricity customers formed a presumed "silent majority," who wanted cheap, reliable electricity without any accompanying complications. They wanted to avoid the hazards and environmental problems associated with new power plants, while enjoying both the electricity services and the local tax revenues provided by them.

<u>Environmental Groups</u>: Environmentalists disapproved of a number of the activities of the electric power producers, and different groups focused on different issues. Some groups, the Massachusetts Public Interest Research Group (MassPIRG) and the Union of Concerned Scientists, for instance, perceived nuclear power as a multi-faceted threat that was hazardous to public safety when operating, produced long-lived, deadly waste streams, and was not a cost-effective electricity source. They and many others worked to prevent the new nuclear plants, such as Seabrook, from coming on-line, and sought to close down existing plants, such as Pilgrim (Pollard, 1988).

Other groups tackled local problems, seeking to prevent plants, transmission lines, and fuel pipelines from being sited near their communities. They feared water pollution, noise, visual blight, infrastructure degradation, and health and safety hazards. Still other groups targeted the air pollution problems caused by burning fossil fuels to produce electricity, including smog and acid deposition caused by SO_x and NO_x, as well as CO_2 and O_3-induced global warming (Boston Globe, 1988a).

Most environmentalists preferred to equilibrate electricity supply and demand by making only demand-side (conservation) investments. Many of them believed that the region could not easily accommodate more power plants, and that the environmental impacts of existing plants needed to be reduced. Indeed, some felt that regional growth should be slowed, because the local environment could not sustain the currently heavy levels of abuse. Conservation investments were perceived as being more cost-effective, and having dramatically lower environmental impacts than the traditional supply-side alternatives. Led by the Conservation Law Foundation (CLF), they worked actively to prevent new supply-side investments by the utilities, and proposed a demand-side emphasis instead (Boston Globe, 1987).

Government Regulators: The regulators were the least monolithic stakeholder group. Most of the state regulators were dissatisfied with the high costs of new utility-owned (nuclear) generating capacity, and wanted to explore alternatives. Following FERC's lead under the Public Utilities Regulatory Policies Act (PURPA) in 1978, many state public utility commissions sought to foster competitive markets in power generation. They did so by requiring the utilities to purchase power offered to them by cogenerators and small power producers, at rates up to the avoided cost of new utility-owned generation. Public utility commissions also encouraged utility-sponsored demand-side efforts, and actively sought to steer the utilities away from large generation projects (Boston Globe, 1988d).

Other state agencies, such as the Energy Facilities Siting Council in Massachusetts (in conjunction with the State Energy Office), favored conservation and other demand-side investments above new generating capacity. Their rationales varied. For example, given that the Siting Council's mission was to minimize the adverse impacts of power plant siting, the most direct way to achieve this was not to let any plants be built. If conservation efforts could dampen demand, then this no-build strategy would be viable. In contrast, the Massachusetts Attorney General's Office advocated conservation as an alternative to bringing Seabrook on line, which they opposed on health and safety grounds. Both of these agencies worked actively to block existing utility supply-side plans (Boston Globe, 1987).

There was no unanimity across states, however. While many of the state agencies in Massachusetts and Maine gave conservation, load management, and non-utility generation their first priority, New Hampshire worked towards a supply-side answer in the form of Seabrook. Rhode Island also accepted a large (gas-fired) supply-side commitment, when the non-utility Ocean States project, which would increase the state's generating capacity by almost one quarter, was sited there. Connecticut, in the unusual position of enjoying excess local capacity, discouraged further utility supply-side plans while offering modest incentives to demand-side measures. Vermont, concerned that it was becoming an energy conduit for southern New England, sought to balance in-state supply investments to meet local demand (Russell, 1989; Boston Globe, 1987).

Federal agencies presented an equal diversity of views regarding New England's electricity situation. The Environmental Protection Agency (EPA) was concerned with persistent air quality problems in parts of the region, dating back to their reluctance to permit the conversion of oil-fired power plants to coal following the Arab oil embargo. They also worried about the safe disposal of hazardous wastes generated by power plants, and sought to minimize other problems related to the supply-side. Both the Nuclear Regulatory Commission (NRC) and the Federal Emergency Management Administration (FEMA) became deeply involved with the Seabrook issue, trying to ensure that the embattled plant would start operation. FERC worked to expand the role of (primarily gas-fired) independent power producers as mandated by PURPA, as well as rationalizing interstate gas and electricity flows. They were typically more lenient than the state public utility commissions regarding the pricing of interstate (but often intra-company) bulk power purchases. The U.S. Department of Energy (DOE) simultaneously encouraged conservation and nuclear power through its R&D expenditures, and discouraged the use of oil and natural gas in power plants, as ordered by the Fuel Use Act of 1978 (Henderson et al, 1988; USDOE, 1986).

<u>Independent Service Providers</u>: A final stakeholder group consisted of independent power producers and conservation services providers. They wanted to ensure a stable, growing market for their services in the region. Thus, they actively worked to prevent utility-owned generation from becoming the option of choice.

The many stakeholders in the regional electricity debate differed widely upon the planning choices to be made to avert a crisis. There was strong polarization over the technological path to be followed. This led to a state of paralysis, during which it seemed that no positive action was being taken in any direction.

Recent Positive Developments

The debate has recently moved off of dead center. Some communication between the opposing camps is now starting, and the major players in regional electric power policy are beginning to talk with one another. Environmentalists, utility personnel, independent power or conservation producers, regulators, employees of other government agencies, customers, and business leaders are involved in a variety of ad hoc, issue-specific discussions throughout New England. For example, the conversion of New England Power Company's Brayton Point power plant from oil to coal probably could not have been accomplished without mediated meetings between concerned parties in the federal and state government, industry, and other stake-holding groups (Bacow & Wheeler, 1984). Similarly, "Boston Edison Company initiated negotiations with consumer, environmental, and business groups in order to arrive at a "consensus" demand forecast for presentation to the Massachusetts Energy Facility Siting Council" (EEI, 1987).

The Massachusetts Department of Public Utilities (MA DPU) sponsored informal, multi-party brainstorming sessions to aid in the formulation of proposed new regulations (MA DPU Orders 86-36-F and G/89-239, 1988-1990). One purpose of the proposed regulations is to reduce the regulatory risks of utility supply- and demand-side investments by granting pre-approval for major expenditures. Another goal is to introduce broader public concerns (environmental, cost) into utility plans. A further aim of this effort is to encourage demand-side investments by utilities, by: (1) allowing them to earn a return on capital invested in conservation projects, and (2) mandating an "all-resource" planning approach, that lets supply- and demand-side options compete directly with one another. A final objective is to further develop a competitive market for electricity by ensuring a place for cogenerators and independent power producers in the utility planning portfolios. The proposed regulations address interests of many of the stakeholders, and all have been invited to participate in a non-adversarial way in the informal discussions. The formal rulemaking and hearing process remains in place to air subsequent disagreements.

Environmental groups, academics, several state agencies, and a number of utilities operating in Massachusetts have started holding workshops, at the request of the MA DPU (TBS, 1989). Their purpose is to work out a method for calculating the shadow price of pollution that will be applied in cost-benefit analyses during utility "all-resource" planning efforts.

Some of the utilities are likewise accommodating their regulators and interveners, and opening up their planning process by seeking third party bids for all new capacity, undertaking demand-side investments, and working directly with interveners on plans. For example, New England Electric, and more recently Commonwealth Electric, Northeast Utilities, Boston Edison, Fitchburg Electric, Eastern Utilities, and Central Maine Power, have contracted with CLF to provide them with demand-side management program designs. This collaborative effort "to design conservation and load management in an expedited manner" has been endorsed by the public utility commissions and other state agencies, and its costs will be passed through to utility customers (Russell, 1989).

Informal sessions on a variety of subjects have taken place. There have been breakfast meetings between senior personnel at CLF, New England Electric, and Raytheon, arranged by an interested neutral (Common Ground, 1989). The focus of my research is a larger, similarly diverse group that has participated in scenario analysis exercises at the MIT Energy Lab (AGREA, 1989c).

The New England Project

This section outlines the alternative, "open" planning project that provided the framework within which my experiments took place. What follows below is my conception of this evolving process, and an illustration of the types of interactions that have taken place.

In 1987, (then) New Hampshire Governor Sununu visited MIT and asked that academics get more directly involved in the regional electricity debate. What he had in mind was publicity on behalf of the beleaguered Seabrook power plant. What he got instead was a small group of faculty, staff and students (including myself) offering to do scenario analysis, to explore how different options fared across a variety of visions of our uncertain future, measured along multiple attributes.

This modeling effort was encouraged by several of the major players in New England, including CLF, the Massachusetts DPU, and NEPOOL, some of whom had experience with previous efforts of this sort in the region. In order to test the viability of this sort of interaction, NEPOOL organized a small advisory group, in January 1988. The analysis team was supported by internal funding from the MIT Energy Lab.

Starting in March 1988, monthly advisory group meetings were held at MIT. Initially, the analysis team presented work that demonstrated its modeling capabilities and revealed its analytical assumptions. These were subsequently modified in response to advisory group members' suggestions. At each meeting, the previous month's analytical work was reviewed, and lessons were drawn. Then further concerns of advisory group members were elicited. During the year, a variety of topics were explored in this way. At the request of advisory group members, we also made presentations to their organizations and to interested parties, such as the Massachusetts AFL-CIO Energy Policy Committee, consulting firms, and gas utilities.

In January, 1989, NEPOOL member utilities and other interested parties formed a consortium to fund the MIT analysis team. At its first meeting in April, 1989, the project sponsors and MIT reached agreement on the structure of the project (advisory group and analysis team) and the composition of the project's advisory group (representation by all major stakeholders, flexible but by invitation only). At subsequent meetings, an expanded advisory group met that included representatives of about twenty stake-holding groups, specifically DPU Commissioners from several states, environmental spokespeople, business leaders, utilities, and members of the New England Governors' Conference Power Planning Committee.

The way we chose to achieve meaningful long term public participation was to arrange iterative exchanges. In these, an advisory group of interested parties, representing the range of opinions and perspectives relevant to the project, explores the tradeoffs between different project options, using information supplied by an analysis team, i.e., those of us working on the project at the Energy Lab.

Both the advisory group and the analysis team have certain roles to play within the framework. The responsibilities of the advisory group members in this process are to: (1) Identify issues and concerns; (2) Invent strategies and identify options; (3) Accept or reject modeling approaches and assumptions; (4) Express the concerns of their constituencies in discussions about the tradeoffs among options; and (5) Work creatively towards a consensus on the choice of favored sets of options.

The responsibilities of the MIT analysis team in this process are to: (1) Assemble data and models; (2) Articulate assumptions, methods, and results clearly (no black box modeling); (3) Respond to the interests, queries, and proposals of advisory group members; (4) Assist the advisory group in inventing better options and packaging them into coordinated strategies; and (5) Assist the advisory group in moving towards a shared understanding of problems, options and system interactions.

Regular interactions between the advisory group and the analysis team are structured to allow an iterative exploration process converging on a consensus planning strategy. This advisory group /analysis team arrangement, using methods explicitly designed for conducting tradeoff analysis, was designed to produce outcomes that are more efficient, equitable, stable, and wise than those resulting from traditional plans produced by experts working in relative isolation.

As an example of this process, I follow the evolution of one topic that the advisory group asked us to explore. At a meeting, a businessman (Senior Vice President, Raytheon Inc.) recalling the previous summer's outages asked: "How much would it cost to improve the reliability of the region's electric power system?" Following that meeting the analysis team gathered data and operationalized a capacity expansion and production costing model of the New England power system. We also pondered, what does electric reliability mean to a businessman? To help him understand out results, we developed "Danger Hours," a measure of the number of hours each year that industrial customers could expect emergency interruptions to occur. We then modeled an increase in the system's reserve margin, from 20% to 25%, across a variety of uncertainties. We found that this strategy gave an average reduction in Danger Hours of 60%, for an average cost increase of only 0.5%, with an average 6% decrease (each) in the emissions of SO_x, NO_x, and suspended particulates.

We presented these results at the next meeting, and the advisory group was inspired to suggest several additional reliability-related options. These included a change in the generation mix used to reach the higher reserve margin, a change in the fuel mix used for new capacity, and the replacement of all old capacity (>40 years old) with new units. After that meeting, we modeled these different options, and found that most options revealed low cost impacts, some options' performance varied widely across uncertainties, some options had better environmental performance than others, and that the dominated options were clearly identified.

The small set of reliability-related options remaining on the tradeoff frontier were discussed by the advisory group during its next meeting, with the replacement of old capacity becoming the preferred option. The low cost of the reliability improvement surprised the advisory group, as did the consistent environmental gains. It appeared that the business interests could get a cheap reliability increase while environmental interests could get a cheap emissions reduction. Everyone at the table seemed happy to have found a possible win-win outcome through this iterative process.

This project continues to enjoy increasing advisory group membership as its analytic results get disseminated and accepted. The next two sections illustrate the initial steps of the scenario-based multi-attribute tradeoff analysis approach as applied to the New England project. The first step is to identify issues and attributes, while the second is to develop scenarios. The remaining steps will be dealt with in subsequent chapters.

Step One: Identifying Issues and Attributes

The first task in the open planning process outlined in the previous chapter is to identify issues to focus the analysis upon, and attributes by which to compare the performance of different options. This scoping exercise began while preparing for the April 1989 meeting of the advisory group. The members of the MIT analysis team had a brainstorming session and generated the following list of broad issues to start the discussion at that meeting: (1) Demand: Forecasting and Impact of DSM; (2) Supply: Technologies and Fuels; (3) System Performance; (4) Intra-Regional Resource Allocation; (5) Environmental and Societal Impacts; and (6) Financial and Regulatory Impacts. We also provided detailed lists of sub-issues within each of these categories. The first category above, for example, included the sub-issues shown in Table 5-1.

Table 5-1: Demand Sub-Issues for New England

Demand: Forecasting and Impact of DSM
— Demand Forecasting
  Demographic Impacts
  Industrial/Sectoral/Regional growth
  General Economic Trends
  Climatic Trends (Air Conditioning, etc.)
  =
— Strategic, Regional Demand-Side Management Objectives
  Reshaping of Load Duration Curve
  Use of/Reliance on Rates, Market Forces
  =
— Demand-Side Management Programs
  Industrial— (Process Modifications)
  Commercial— (Lighting and Space Conditioning)
  Residential— (Appliance Standards, Lighting, Space Conditioning, etc.)
  Transportation— (Public Transit, Electric Automobiles, etc.)
  =
— Effectiveness of Demand-Side Initiatives
  Initial quantities
  Customer responsiveness
  Saturation effects
  Program economics and costing
  =

During the April 1989 meeting, these examples sparked discussion of what was: (1) most important to study, and (2) feasible to analyze given our budget and skills. For instance, environmental impacts were widely regarded as crucial elements of the study scope. By contrast, the issue of intra-regional resource allocation was postponed because the Energy Lab did not then have any computer modeling capability in that area. After a lengthy discussion, the advisory group came to a consensus that the MIT analysis team's efforts should focus on the environmental and reliability impacts associated with different electric service strategies. The participants were also provided with a take-home packet containing modeling assumptions to review, a glossary, and examples of attributes, uncertainties, and options that could be modeled.

Representation was the other major issue discussed at the April 1989 meeting. The electric utility sponsors agreed that additional representatives from the region's regulatory agencies, environmental organizations, business and consumer interests should be invited to join the advisory group. However, due to the highly specific interactions between the advisory group and the MIT analysis team, the decision was made not to issue an open invitation to the public at large, but instead to invite a "representative" group of about twenty New Englanders who were well-known in regional energy policy debates, who could attend regularly (and not merely send alternates).

Existing channels were used where possible, including the New England Governors' Conference Power Planning Committee (government), the New England Council/ Business Roundtable (business), and the Collaborative Process participants (environmental organizations). Current participants recommended other potential invitees, and all meetings were open to all who showed up.

During the second meeting, in June 1989, which enjoyed a much broader range of stakeholder representation than the previous meeting, the sub-issues within the broad areas of environment and reliability were prioritized. The option to introduce other issues remained available but was not used by any of the ten participants who attended. Details of the attributes, uncertainties, options, and strategies were discussed, but the group ran out of time before these factors had been prioritized. A follow-up questionnaire elicited the participants' priorities for each. Out of the fourteen questionnaires sent out, ten were returned, by regulators, environmentalists, and utility personnel. The highest-ranked sub-issues (and attributes) were as shown in Table 5-2.

Table 5-2: Issue/Attribute Ranks for New England

Sub-Issue (Attribute)	Votes
Acid Deposition/Air Quality (SO_2, NO_x)	7/10
Climate Change (CO_2)	6/10
Reliability (NEPOOL O.P. 4 Emergency Status)	5/10
Cost (Revenue Requirements)	4/10

These were selected by the respondents from a list of dozens of sub-issues and attributes (see Appendix B3). It is important to note that these were the sub-issues around which the participants felt we should focus the study, and did not necessarily represent their perceptions of the relative importance of each for choosing between options.

In developing the computer modeling capability, the analysis team cast the net more widely, measuring a variety of environmental, reliability, cost, and performance attributes. Table 5-3 lists the primary issues and attributes the MIT analysis team evaluated based on the New England advisory group's interests. Additional, secondary issues and attributes were also evaluated so that a fuller understanding of the system's behavior could be attained.

Table 5-3: Issues and Attributes for the New England Project

Primary Issues

- Environmental impacts of different supply/demand strategies
- Reliability of electricity supplies given supply/demand strategy and uncertainties

Primary Attributes

- SO_2, CO_2, NO_x, and Particulates Emissions (cumulative for the region over 20 years)
- Megawatts of power plants to be built at new sites (a proxy for site-related environmental impacts)
- NEPOOL Emergency Operating Procedure 4 "Danger Hours" measuring the magnitude and duration of reliability problems
- Cost of Electricity (total costs including capital and operating costs, plus customer and utility investments in conservation and load management)

Secondary or Descriptive Attributes

- Cumulative consumption of different fuels over the study period
- System-average combustion efficiencies (fossil heat rate, system heat rate)
- Utility and Customer investment trajectories in supply and demand-side projects
- Electricity production and sales; energy and peak

A total of 41 attributes were modeled.

Step Two: Developing Scenarios

The previous chapter pointed out that issues are translated into analyzable form by defining scenarios. These allow us to examine the performance of combinations of options (strategies) across a variety of uncertain future events (futures). In the New England project, the MIT analysis team brainstormed a variety of options and uncertainties to provoke discussion, elicited comments on them in the June 1989 questionnaire (shown in Appendix B3), and then asked the advisory group to prioritize them during the August 1989 meeting.

The June 1989 questionnaire results were inconclusive; that is, no technologies were ruled out, and only gas-fired generation and demand-side management received repeated endorsements, although a wide variety of options piqued the interest of individual respondents. The MIT analysis team therefore constructed a large number of uncertainties, options, and strategies, and asked the advisory group to prioritize them in order of decreasing interest.

Out of nine uncertainties proposed at the August 1989 meeting, the group chose four by consensus as their highest priority. These were load growth, fuel prices, demand-side program cost-effectiveness, and environmental regulations. The remainder were relegated to sensitivity analysis, to be studied for a subset of dominant strategies if requested by the advisory group. They did not request this for more uncertainties, but sensitivity runs exploring more strategies did get run. The group also selected six supply option sets, based loosely on a subset of those proposed by the MIT analysis team. These were gas-dependent, gas and power purchases, cogeneration, repowering, power purchases and repowering, and clean coal and repowering.

Members of the group balked at the four demand-side option sets proposed by the analysis team, saying that they were not credibly modeled, since they were based on an extrapolation of recent utility demand-side program filings to the regional level. A demand-side subcommittee was appointed to oversee the creation of better demand-side option sets covering the range from "no DSM" to "a lot." This subcommittee recommended that three classes of demand-side options be modeled: utility programs, government standards, and generic subsidies. In order to do this, however, the analysts had to master another major computer modeling tool: NEPOOL's end-use load forecasting model (see Appendix B2). This requirement, in addition to the arrival of an improved version of the production simulation model for analyzing the supply-side, delayed the next advisory group meeting from October to November 1989.

It also led to a change in the uncertainty set to be modeled: environmental regulation was postponed, and the possibility of demand-side program interactions was examined instead. This uncertainty arose as the result of conflicting opinions among experts. One expert, the manager of demand-side planning from the region's largest utility, said that significant overlaps existed between utility-sponsored conservation programs and proposed building/appliance efficiency standards. Another expert, from the lead environmental organization in the collaborative conservation program design process, said that the utility programs could be designed to avoid such overlaps. Since these two could not agree, we modeled it both ways, making it an uncertainty instead of an assumption.

During the November 1989 meeting the analysis team shared interim modeling results with the advisory group. The details of the demand-side option sets were explained, and initial results confirming the accuracy of the models were shared. One counter-intuitive trend – increasing cumulative sulfur dioxide emissions accompanying increasing demand-side efforts – surfaced in the data presented at this meeting, causing the group to appoint an environmental subcommittee to review those modeling assumptions. Their review led to better plant-specific emissions data being provided to the analysis team by the utilities. The interim results were also presented to the NEPOOL Demand-Side Management Planning Committee, consisting of the heads of the DSM departments at each of New England's electric utilities. This group of experts identified additional improvements in modeling demand-side options that the analysis team then executed.

The type of results that were shown in the November 1989 meetings included detailed descriptions of uncertainties such as load growth (see Figure 5-4). The impacts of these uncertainties were revealed along various attributes. For example, Figure 5-5 showed that, on average, both higher fuel prices and higher load growth led to higher total electric service costs. These results followed the dictates of common sense.

Following the interim corrections, the analysis team proceeded to run a full set of scenarios. As mentioned previously, the building blocks of a strategy (e.g. Gas-Dependent New Capacity and High DSM) include a supply option set (Gas-Dependent New Capacity) and a demand-side option set (High-DSM), which in turn are built from individual supply options (for example- Gas-Turbine Combined-Cycle plants) and demand-side options (e.g. Residential Appliance Efficiency Standards). Table 5-4 lists the individual options and option sets used to construct the strategies analyzed for the February, 1990 meeting of the New England project advisory group. As can be seen, fifteen demand-side option sets, combined with four supply-side option sets yield a combined total of sixty strategies. A broad range of demand-side programs, coupled with supply side technologies including power purchases, new capacity, repowering of old capacity, and cogeneration allow a wide variety of strategies to be evaluated.

A future represents a specific combination of uncertainty values (e.g. Optimistic Economic Growth and On-Budget DSM). Each uncertainty is modelled by using at least two different values for a particular variable (for example - Optimistic and Pessimistic Economic Growth). Equal probabilities are assigned to the different futures during the early stages of analysis in order

Figure 5-4: New England Project Load Growth Uncertainty
Source: AGREA 1989a

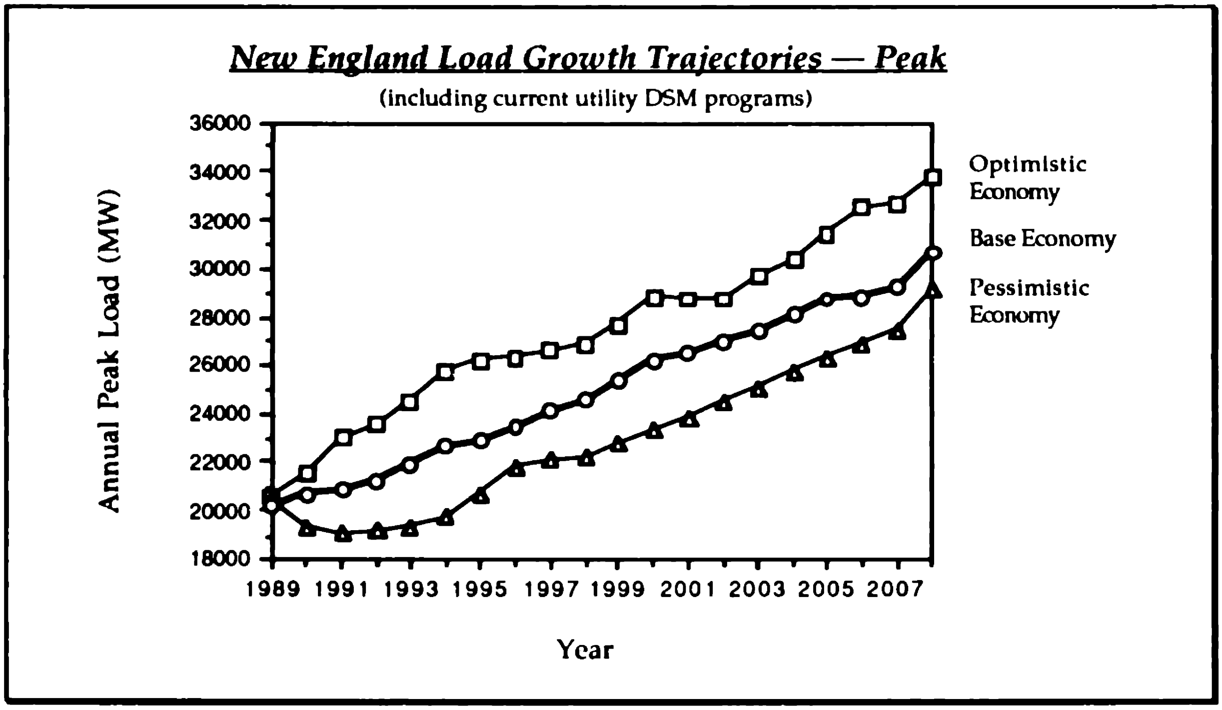
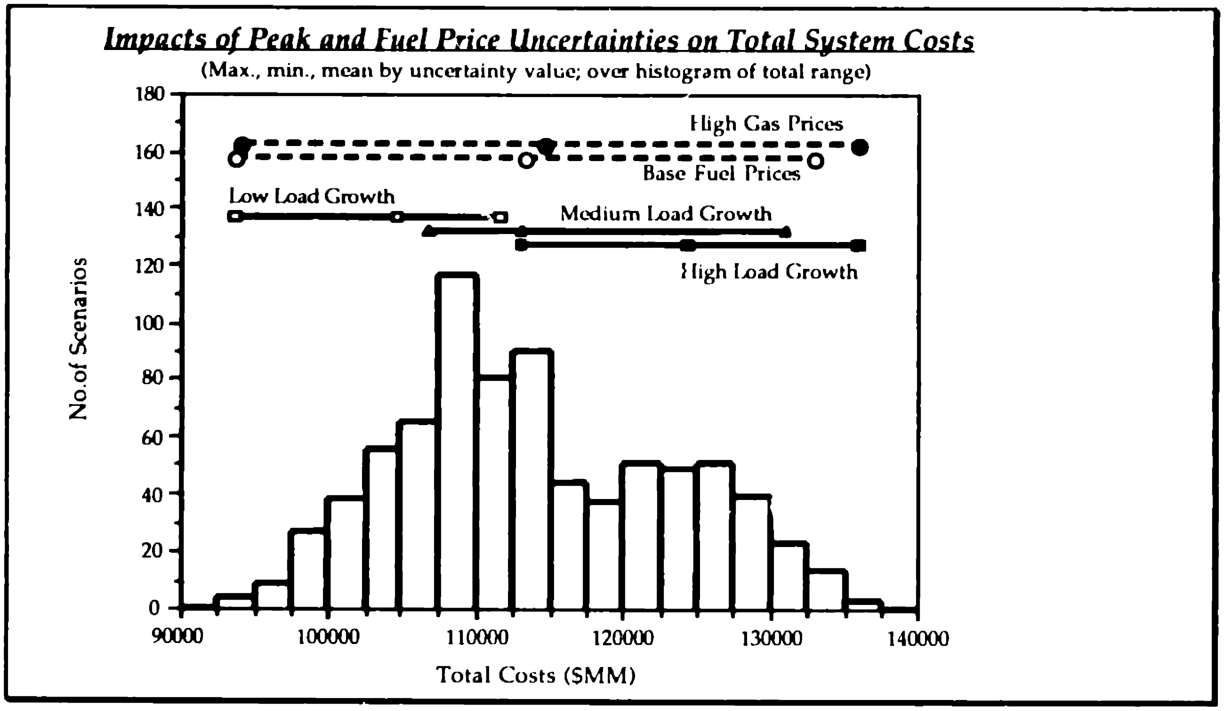


Figure 5-5: Effects of Uncertainties on Cost in the New England Project
Source: AGREA 1989a



to minimize the subjective content of the data in the forthcoming tradeoff analysis. While prioritizing issues to analyze in the discussions and questionnaires, the group also identified the uncertainties which concern them most. Those incorporated into this set of scenarios are listed in Table 5-5. These 36 futures combined with the 60 strategies to form a total of 2160 scenarios.

The multi-attribute impacts for each of the 2160 scenarios were modeled using a partially integrated set of computer models (see Appendix B2 for a description). The resulting data set was then analyzed using the applied statistical and graphical techniques outlined in the next two chapters.

Table 5-4: Strategies for the New England Project
Source: Andrews et al 1990

Strategies

Options are combined into Option Sets which are in turn combined into Strategies.

Supply Option Sets

Technology Options	Gas Dependent	Power Purchases and Gas	Repowering and Gas	Repowering and Purchases
(New Capacity)	(%-New MW)	(%-New MW)	(%-New MW)	(%-New MW)
Combustion Turbine 80	20%	10%	10%	5%
Combined Cycle 200	70%	45%	——	——
Cogeneration 40	10%	10%	10%	10%
Power Purchases	0%	35%	0%	35%
Life-Extend Existing Units	No Retirements	No Retirements	None except Repowerments	
Repower Existing Units	None	None	80%	50%

Demand-Side Option Sets

Options Utility Programs	*Residential Appliance Eff. Stds.*	*Commercial Building Eff. Stds.*	*Commercial Lighting Subsidies*	*Commercial HVAC Subsidies*	*Combined Strategies*		*(Key)*	
—	—	—	—	—	A0	A1	A2	A3
—	■	—	—	—	B0	B1	B2	B3
—	—	■	—	—	C0	C1	C2	C3
—	—	■	■	—	D0	D1	D2	D3
—	■	■	—	—	E0	E1	E2	E3
—	—	■	■	■	F0	F1	F2	F3
—	■	■	■	■	G0	G1	G2	G3
■	—	—	—	—	H0	H1	H2	H3
■	■	—	—	—	I0	I1	I2	I3
■	—	■	—	—	J0	J1	J2	J3
■	■	■	—	—	K0	K1	K2	K3
■	—	■	■	—	L0	L1	L2	L3
■	—	■	■	■	M0	M1	M2	M3
■	■	■	■	—	N0	N1	N2	N3
■	■	■	■	■	O0	O1	O2	O3

Table 5-5: Futures for the New England Project
Source: Andrews et al 1990

Futures — *A future is a combination of different uncertainties*

Load Key	*Economic Growth*
H	High/Optimistic
L	Low/Pessimistic
M	Medium/Base

DSM Cost Key	*DSM Cost Effectiveness (¢/kWh)*
C	On-Budget DSM Programs and Measures
E	50% Cost Overrun—Programs and Measures
B	50% Cost Underruns—Programs and Measures

Fuel Key	*Fuel Prices*
F	Base Fuel Prices
G	High Nat. Gas Prices

Impacts Key	*DSM Interactions (GWh & Peak)*
D	No Interactions - Utility Progams and Measures
5	50% Reduction in Utility Programs/Interactions

Efficacy of the Initial Steps

The New England electric power planning debate was mired in controversy, uncertainty and complexity, which prevented constructive discussion about the region's options and led to planning paralysis. As one among several efforts to move the debate off dead center, the New England open planning project at MIT has provided a vehicle for joint fact-finding by the various stakeholders in the regional electric power planning debate. The initial steps in this process, although imperfect, nevertheless encouraged all of the participants to continue forward with this effort.

There was an initial concern that the project would be considered by environmental groups to be tainted because it was funded by utilities and businesses. Similarly, while MIT was considered a credible neutral to some parties, it was considered a "tool of industry" by others. Thus, the analysis team had to prove that it was worthy of everyones' trust. It took several months of regular interactions among the stakeholders and the analysis team for technical credibility to be established, and one environmental organization continues to have our results monitored by their own outside consultant as a check against biases. The MIT analysis team has sought out constructive criticism of this sort to avoid the possibility of "adversarial science" later on.

The process itself also had to overcome a credibility hurdle because it was not completely "open." Participation nominally required an invitation. In practice this became a moot issue, because all were welcome at the actual meetings, and no-one (that we know of) felt excluded.

A questionnaire soliciting participants' feelings about the project was sent to all advisory group members after the November 1989 meeting (see Appendix B3). Twelve of the eighteen advisory group members responded; the majority of these were utility personnel and regulators. Their greatest concerns regarding the feasibility of this planning process are listed in Table 5-6 (only the top five are shown).

Table 5-6: Greatest Concerns Regarding Feasibility of New England Project

1.) Differing perceptions of main issues
2.) Polarization around different options
3.) Disparate values for non-dollar "intangibles" (pollution impacts, catastrophic risks, etc.)
4.) Conflicting interests of parties
5.) Unequal background/technical understanding

Most of these factors are present in any public dispute. At this stage of the process, the only one that seemed to provide a serious threat was the last, unequal background. Specifically, the main environmental spokesperson felt inadequately prepared to critique the detailed modeling assumptions that were used. This imbalance was addressed both by special visits from analysis team members, and by an arrangement whereby their technical expert in the Collaborative Process, whose time was paid for by the utilities, attended the advisory group meetings.

A factor that made the top five in the post-game survey described in Chapter Three – conflicting technical information – was not highly ranked by the New England project advisory group. This suggests that some of the credibility problem may have been overcome by the time this questionnaire was sent. The analysis team's successful response to the demand-side management modeling complaint was one of the keys to building credibility, the others appear to have been: (1) adequate documentation of assumptions, (2) sharing intermediate results with the advisory group so that the final results were not a surprise, and (3) exploration of a wide range of options and uncertainties to confirm the robustness of the results.

The scenario-based analytic approach seems to have assuaged another prominent concern expressed in the post-game survey: uncertainty about the future. The New England group ranked this quite low, in eighth place.

The major goals that the respondents identified for this project reflected the concerns listed above, and were consistent with the initial project scope. The five most important of these are shown in Table 5-7.

Table 5-7: Goals for the New England Project

1.) Developing a shared understanding of the implications of different choices
2.) Prioritizing the most important regional electricity planning issues
3.) Seeking an informed consensus on a course of action
4.) Evaluating strategies or packages of options for the region
5.) Monetizing intangible impacts, such as pollution costs

The sixth-ranked goal – inventing better strategies than are currently on the table – enjoyed an extremely high ranking in the eyes of the regulators on the advisory group, but was considered less important by the utility participants. This opinion, expressed at the end of the scenario development phase of the project, was to change following the exploration of system behavior described in the next chapter.

In summary, both the technical credibility and neutrality of the MIT analysis team had to be proven over the course of several months; it was not taken for granted. The high level of expertise in the advisory group was one of the things that made this possible, because they could understand the nuances of our intermediate results, pinpoint our technical errors, and confirm the overall credibility of our work. The process of interacting with a wide variety of experts working for the decision makers on the advisory group, and seeking out those representing different points of view, were both crucial in establishing the credibility of the results. Our ability to model multiple futures did indeed minimize controversy about the modeling input assumptions. The data collection effort itself provoked increased levels of communication among the stakeholding groups, at all levels in their organizations, and mostly in informal, low-risk settings.

6. EXPLORING SYSTEM BEHAVIOR IN THE NEW ENGLAND PROJECT

Modeling the multi-attribute impacts of 2160 scenarios for New England's electricity future resulted in the development of a very large data set during January of 1990. The analysis team had to draw "stories" from this data set for presentation at the February 1990 advisory group meeting. The goal of this effort was to explore the behavior of the complex electric power system in order to spur the inventiveness of the participants in creating better strategies.

Table 6-1: Explore System Behavior (Initial Framework)

3.a. Observe the effects of uncertainty.
- *i. Over what ranges do impacts vary?*
- *ii. How relevant are the different uncertainties?*
- *iii. How different are the various futures?*

3.b. Observe the performance of strategies – one attribute at a time.
- *i. How do individual options perform along various attributes?*
- *ii. How does each option set perform along various attributes?*
- *iii. How consistent is the performance of each option set ?*
- *iv. How does each strategy perform along various attributes?*
- *v. In general, how do the strategies rank relative to one another?*
- *vi. How consistent are strategy rankings across different futures?*
- *vii. How volatile is the performance of each strategy given uncertainty?*
- *viii. Do different uncertainties affect different strategies?*

3.c. Observe the performance of strategies – consider multiple attributes.
- *i. How does each strategy perform for different attribute pairings?*
- *ii. How consistent is the performance of each strategy across various possible futures?*
- *iii. How does each strategy perform considering all attributes?*

3.d. Observe the performance of the system.
- *i. Do different attributes correlate with one another?*
- *ii. Do some attributes explain others?*

3.e. Invent better strategies and explore more relevant uncertainties.
- *i. Based on what we have learned about the system's behavior, which additional strategies need to be evaluated?*
- *ii. Are there other uncertainties to consider?*

Repeat steps 1 to 3 above if necessary.....

The approach developed for mining this data was described in Step Three of the framework outlined in the fourth chapter. This included observing the effects of uncertainty, and the performance of strategies and of the system as a whole, across their multiple attributes, using specific graphical and statistical techniques for each task. Each of the tasks is listed in Table 6-1, and then discussed in more detail below, and an example of its use is provided.

Step 3.a. Observe the Effects of Uncertainty

The first step in understanding the behavior of the system is to observe its reaction to changes in exogenous stimuli, the uncertainty values. Since impacts are measured along several attributes, we must look at each of them in turn, and ask a series of questions. Using inductive logic, we hope to infer aspects of system behavior from summary statistical measures and graphical analysis techniques.

3.a.i. Over what ranges do impacts vary?

Examine the global (across all scenarios) range of variability for attribute 'A','B' and so on, using summary statistics (max., min., mean, median, standard deviation) and graphics. For example, selected summary statistics across 2160 scenarios included the information shown in Table 6-2.

Table 6-2: Summary Statistics for Cost, SO_2 and Reliability

Attribute:	Total Cost of Electric Service (1989 \$M)	Sulfur Dioxide Emissions (10^6 tons)	Emergency Status O.P.4 Level 12 (hours)
Sample Mean:	127,417	5.996	127
Sample Median:	125,149	6.040	92
Sample Minimum:	106,330	4.430	34
Sample Maximum:	153,474	7.530	662
Sample Std. Dev.:	14,768	0.719	96

Inspection of these statistics shows the magnitudes of expected impacts and their ranges of variation within the sample. Costs and emissions impacts show more symmetry than the reliability measure of emergency hours. Although all three attributes are cumulative 20-year sums (or NPVs), every kWh of electricity produced affects costs and emissions, whereas emergency hours depend more upon events at the margin; hence the dramatically right-tailed distribution.

Histograms overlaid with normal curves reveal even more about the behavior of the system, as shown below in Figures 6-1, 6-2, and 6-3. Note that the standard units on the left-hand scales measure the proportion per standard unit, standardized by the sample standard deviation, allowing easier comparisons across histograms than the counts on the right-hand scales (it is not the proportion of the sample in each bar).

Figure 6-1: Frequency Distribution of Total Cost for 2160 Scenarios

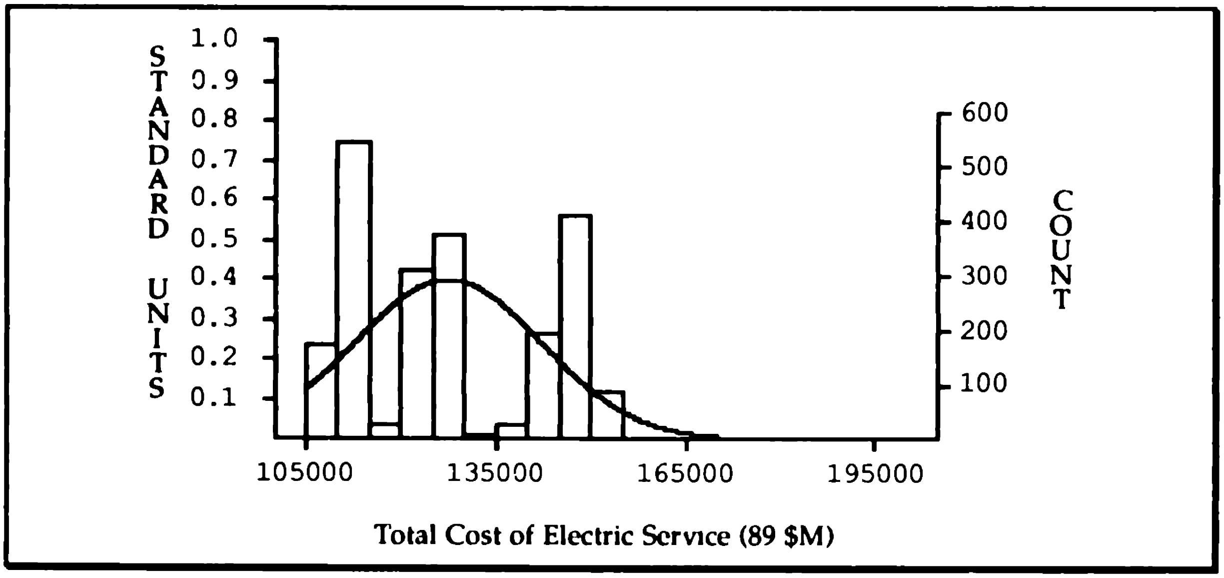


Figure 6-2: Frequency Distribution of Sulfur Dioxide Emissions for 2160 Scenarios

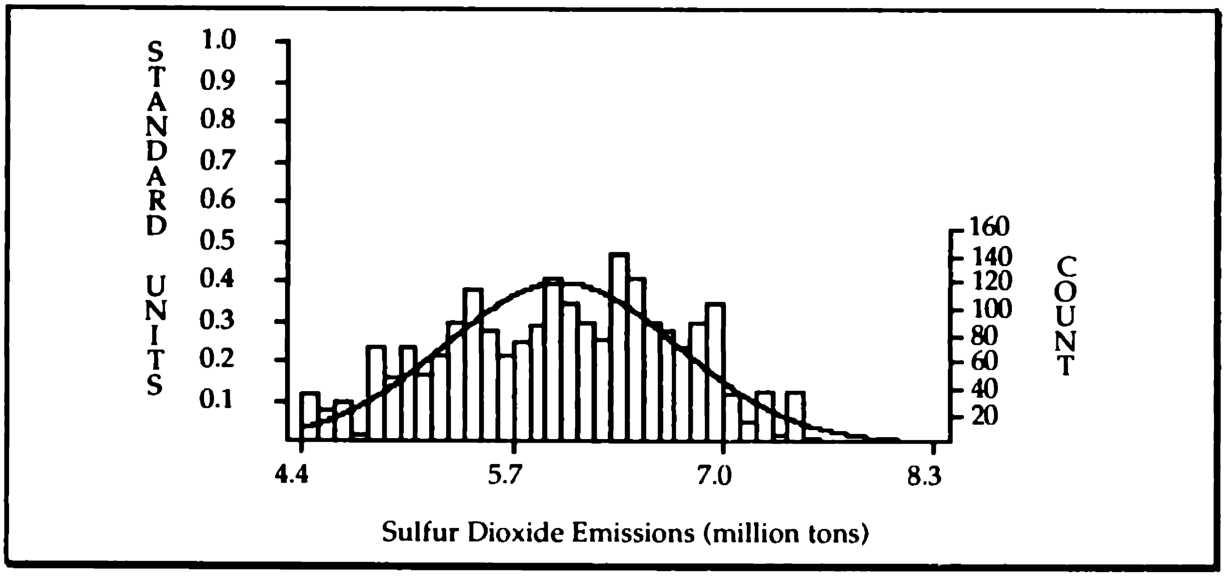
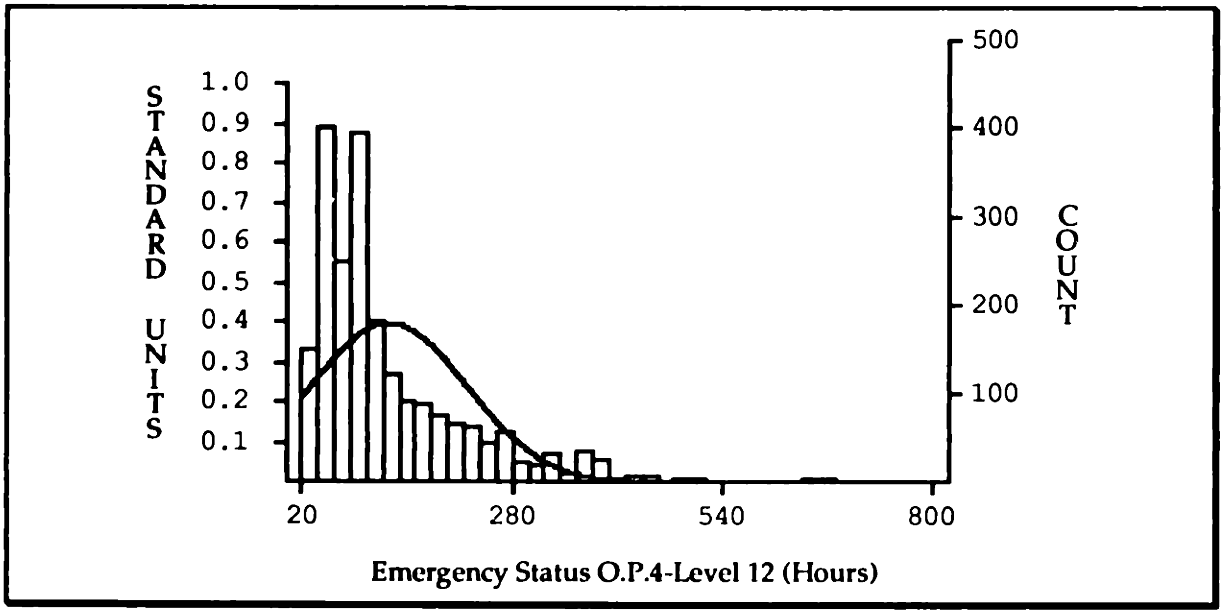


Figure 6-3: Frequency Distribution of Emergency Hours for 2160 Scenarios



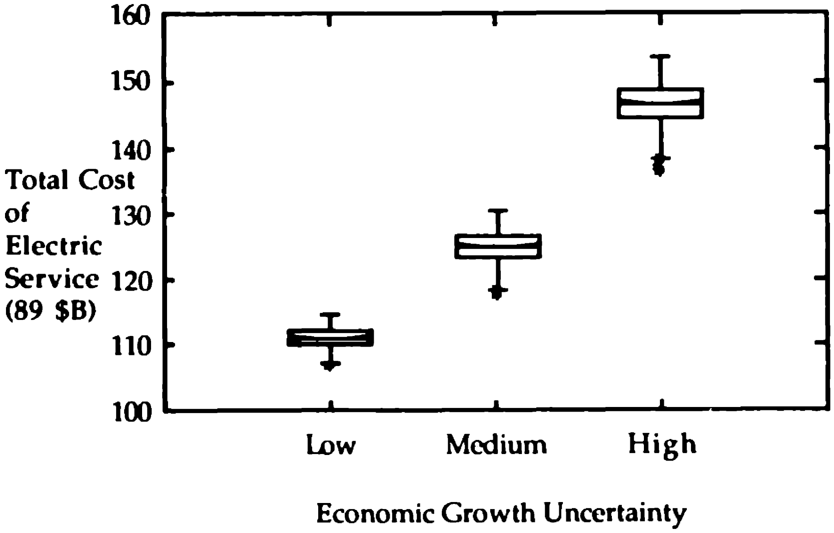
The histogram for emergency hours confirms the right-skewness of that distribution across the sample of scenarios studied. The histograms for cost and emissions reveal that, although impacts are normally distributed overall, there is a distinct multi-modal pattern in the results. This confirms the need to do cross-sectional analysis by uncertainty.

3.a.ii. How relevant are the different uncertainties?

Examine uncertainty-value-specific variability (across all scenarios sorted by uncertainty value) of attribute 'A', then 'B' and so forth. See examples below.

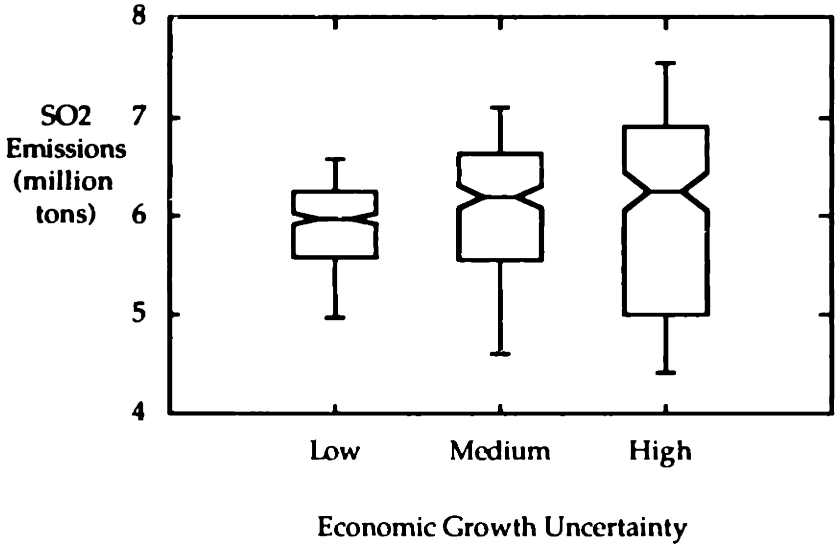
In the set of box-and-whisker plots below (Figure 6-4), the sample of 2160 scenarios has been divided into three groups of 720 scenarios, sorted by economic growth uncertainty value. The tight groupings confirm and explain the tri-modal distribution mentioned above. For the total cost attribute shown, it is clear that none of the strategies in this sample was effective at damping out the effects of economic growth uncertainty. It is also apparent that, for this attribute, the system behaves relatively uniformly in response to economic growth: increased growth leads to increased total costs.

Figure 6-4: Effect of Economic Growth Uncertainty on Total Cost of Electric Service (3 cohorts of 720 scenarios)



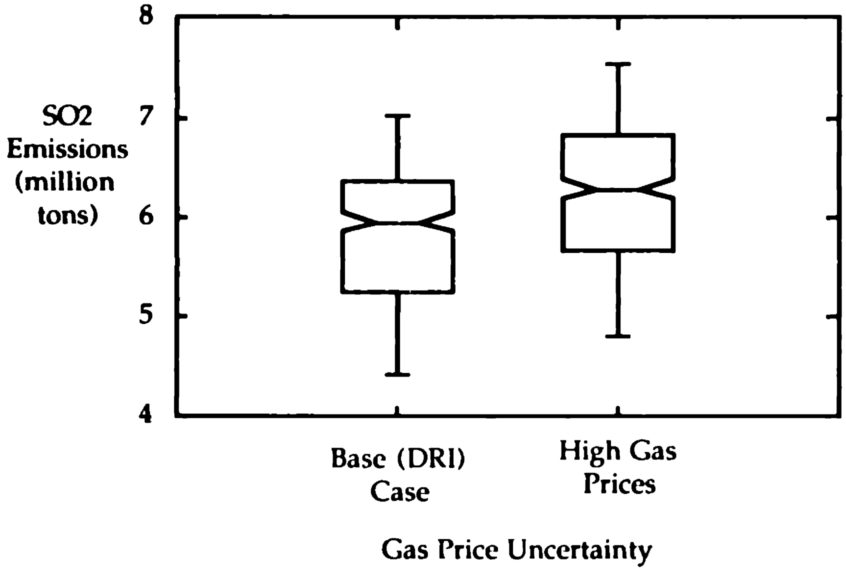
Analysis of the economic growth uncertainty for a different attribute -- sulfur dioxide emissions -- leads to different conclusions. The box-plots in Figure 6-5 below show that while the median emissions levels across the three groups increase slightly with economic growth, so do their ranges. Thus, increased economic growth does not in every case drive the system to increase sulfur dioxide emissions. The strategy chosen, or the combined effects of economic growth with another uncertainty, is able to push the system in the opposite direction in some cases.

Figure 6-5: Effect of Economic Growth Uncertainty on Sulfur Dioxide Emissions (3 cohorts of 720 scenarios)



Just as an uncertainty's effect is not consistent across all attributes, neither are the effects of different uncertainties for a single attribute. For example, Figure 6-6 below shows that higher gas prices lead to higher sulfur dioxide emissions in a uniform way in the New England system.

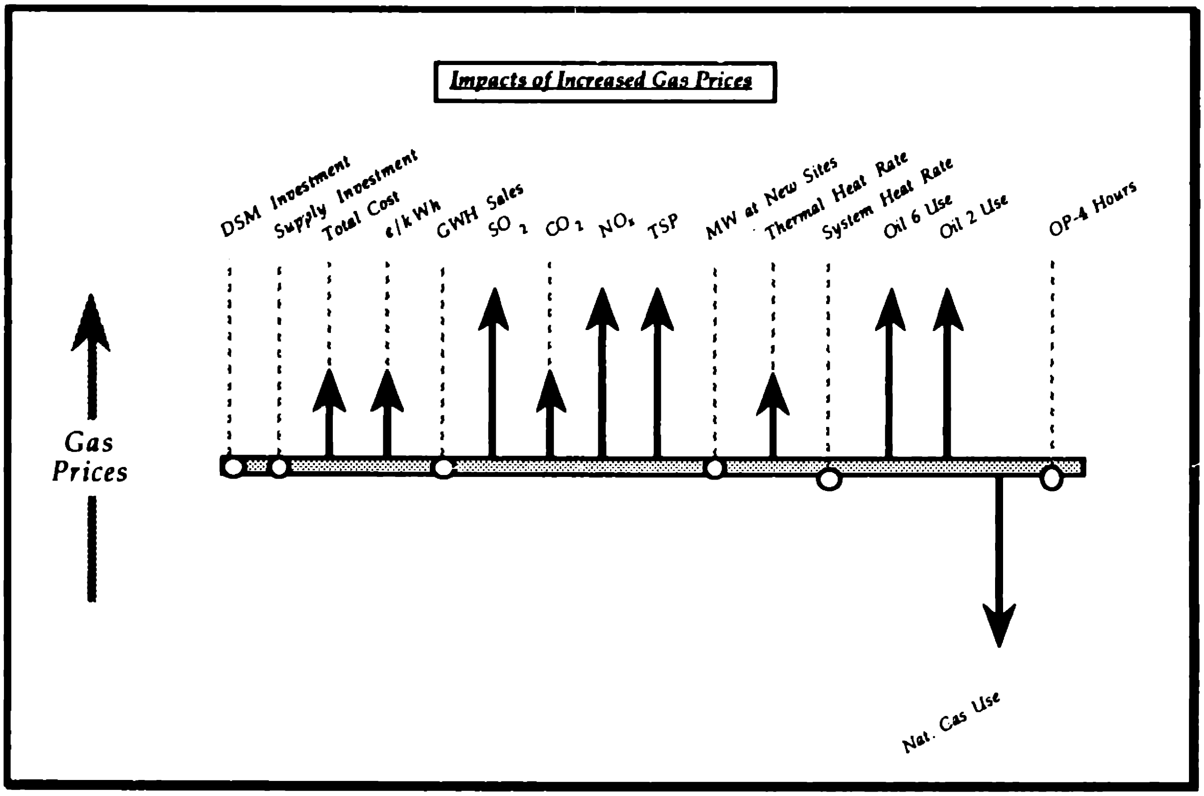
Figure 6-6: Effect of Gas Price Uncertainty on SO2 Emissions (2 cohorts of 1080 scenarios)



When this is repeated for attributes 'B', 'C' and so forth, then the systemic impact of the change in uncertainty value is revealed. This information can be compacted for use with lay audiences as shown in Figure 6-7 below.

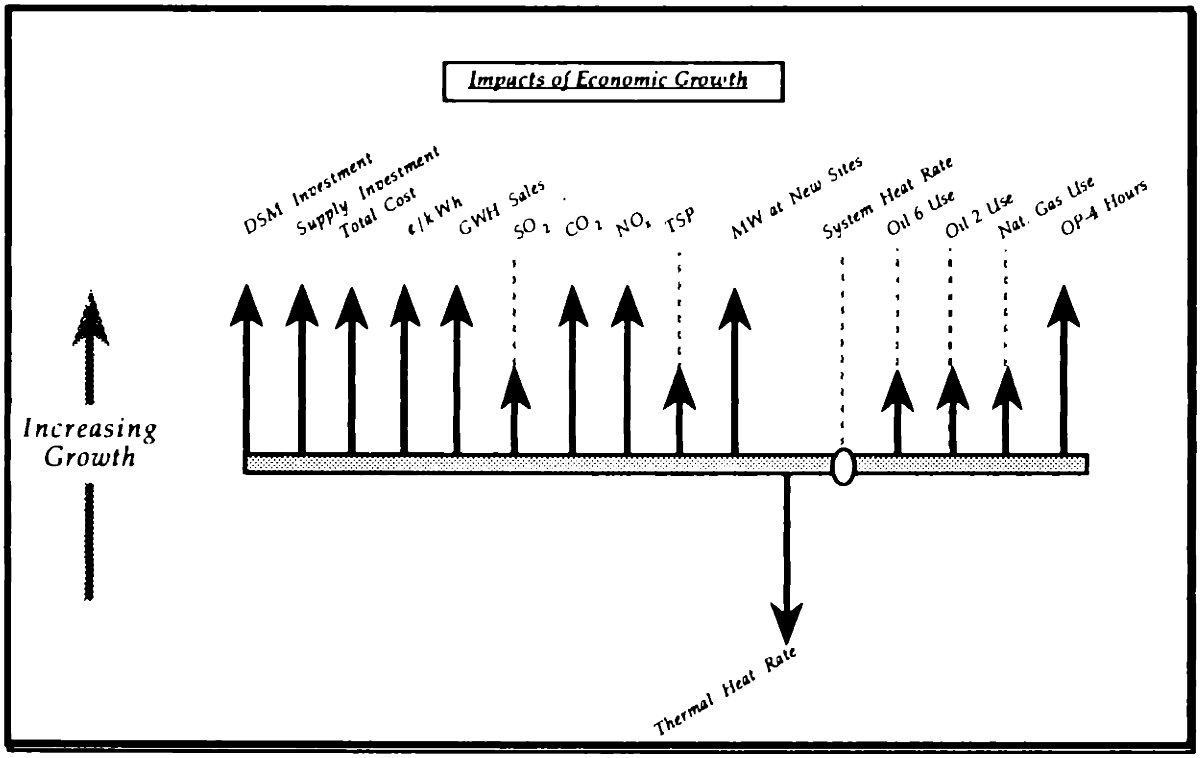
For this sample of 2160 scenarios, it became clear that higher natural gas prices (bringing this fuel into cost parity with Oil 2) led to significantly higher emissions and oil consumption, and slightly higher costs for the New England region. The impact on reliability appeared to be negligible.

Figure 6-7: Effect of Gas Price Uncertainty on System
Source: Andrews et al 1990



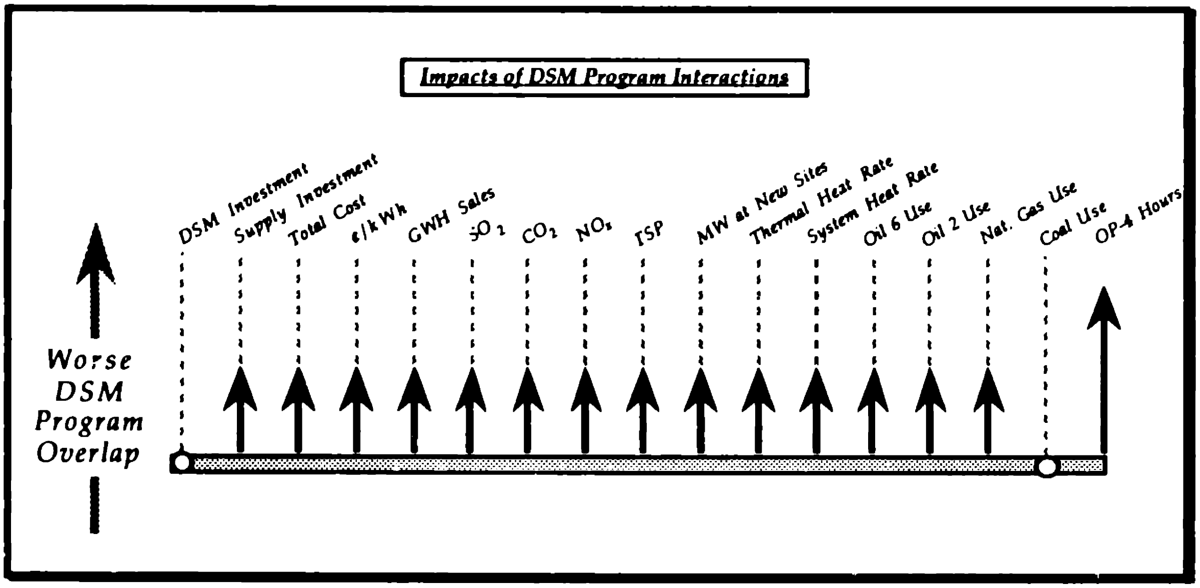
Uncertainty regarding economic growth also revealed itself as a valid concern in this scenario set. Growth profoundly affected costs, reliability, and some environmental impacts, while influencing other environmental impacts and fuel use to a lesser degree. The magnitudes and directions of these impacts are shown in Figure 6-8 below.

Figure 6-8: Effect of Economic Growth Uncertainty on System
Source: Andrews et al 1990



In contrast to the uncertainties shown above, that surrounding demand-side program interactions revealed fewer significant impacts (see Figure 6-9). These interactions had the potential to occur due to redundant program measures or technical potential limitations. Such interactions had their strongest adverse effect on reliability. This was due to the increased difficulty of matching capacity investments to load when DSM program effectiveness was uncertain. Minor changes in cost and emissions impacts were also noted.

Figure 6-9: Effect of DSM Program Interaction Uncertainty on System
Source: Andrews et al 1990



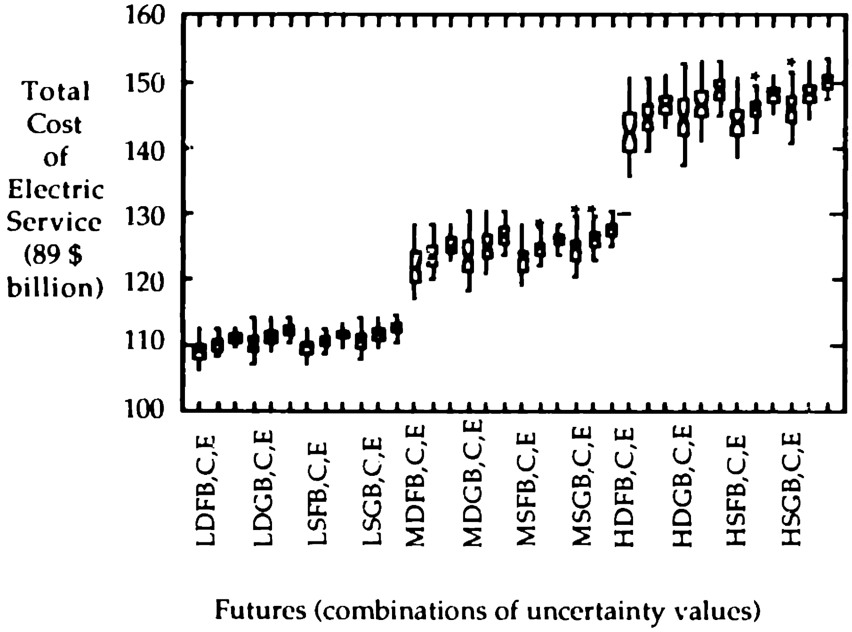
Thus we can mine the data for insights into the behavior of New England's electric power system in response to different uncertainties. Careful construction of a symmetric, exhaustive data set is an important prerequisite for this type of analysis. After this examination of individual uncertainties, which are the components of possible futures, we are ready to look at their combined impacts.

3.a.iii. How different are the various futures?

Divide the data set into future-specific cohorts; analyze these for attribute 'A' and 'B' and so on.

Future-specific analysis shows the combined impacts of various uncertainties, and lets us identify the best and worst of sets of possible circumstances in the experimental sample. In the set of futures shown in Figure 6-10, we can see that for the attribute of total cost, future LDFB is the best (lowest). Using the key in Table 5-5, we see that this is a future with low economic growth, no demand-side program interactions, moderate fuel prices, and inexpensive demand-side program unit costs. The worst future, in cost terms, is HSGE, which is high economic growth, significant demand-side program interactions, high gas prices, and expensive demand-side program unit costs.

Figure 6-10: Future-Specific Ranges for Total Cost
(across 60 Strategies within each of 36 Futures)



The set of box plots in Figure 6-10 also allows us to compare the relative importance of the various uncertainties. This is shown by the relative movement of the boxes with changes in the value of a single uncertainty, holding all other uncertainties constant. For the attribute of total cost, it confirms the primary importance of economic growth (L, M, H), the secondary importance of gas prices (F, G) and DSM cost-effectiveness (B, C, E), and the near irrelevance of DSM interactions (D, S).

Repeating this analysis for each of attributes 'B', 'C' and so on reveals additional useful information about the behavior of the system. Once we have completed this analysis of the effects of uncertainty, we are ready to look at the performance of the option sets and strategies that can be selected by the decision makers.

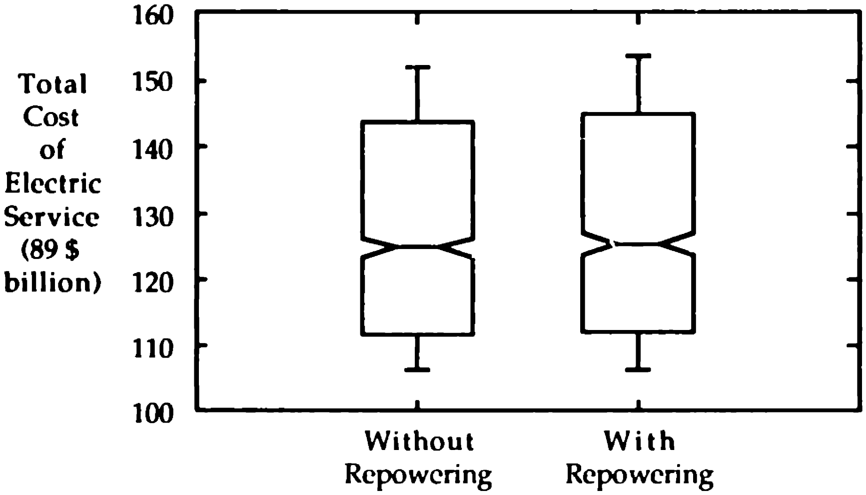
Step 3.b. Observe the performance of strategies -- one attribute at a time

The symmetric data set allows us to analyze the components of strategies (option sets) as well as the combined strategies themselves. This serves to build our understanding of the system's behavior as well as encouraging the development of better strategies. In the discussion above, we started by examining individual uncertainties, and then moved to combined futures. In this section the approach is the same: we will first examine option sets and then strategies. Note that the symmetry of this sample extends only to option sets, not to individual options. We can still study the behavior of options, but not exhaustively. The following questions guide our analytic effort.

3.b.i ***How do individual options perform along various attributes?***

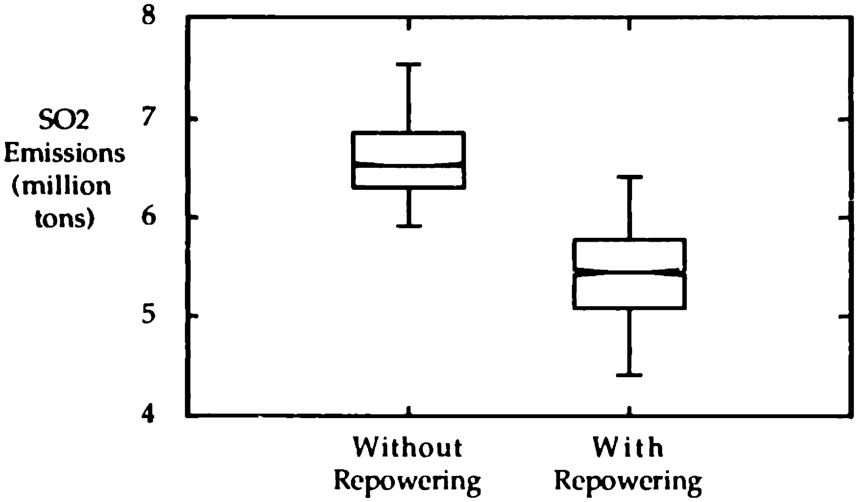
These cannot be exhaustively analyzed since the data set is not uniformly symmetric across options, only option sets. However, simple with/without comparisons are possible. Sort the data set into two cohorts for each option: with and without it, and determine the range of values along attribute 'A', 'B' and so forth. This can be done graphically using box plots.

Figure 6-11: Range of Total Costs with and without Repowering
(1080 Scenarios for each case)



Repowering is a supply option that is combined with other supply options into supply option sets, and then with demand-side option sets into scenarios. One half of the scenarios contain some level of the repowering option. The pair of box plots in Figure 6-11 shows that repowering has very little effect on the total cost of electric service. However, for the attribute of sulfur dioxide emissions a different story emerges (see Figure 6-12). Repowering dramatically reduces those emissions.

Figure 6-12: Range of Sulfur Dioxide Emissions with and w/o Repowering
(1080 Scenarios for each case)

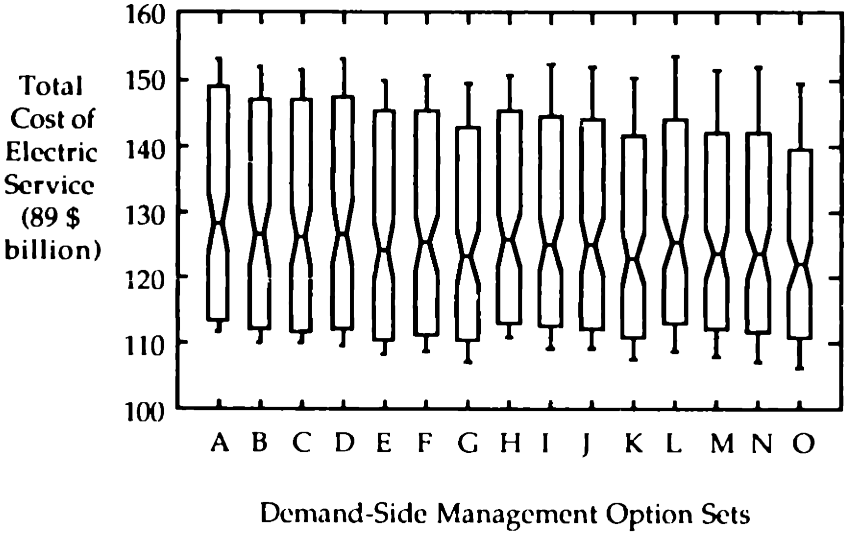


Similar graphs for other options, and for different attributes, will improve our understanding of the characteristics of the options.

3.b.ii. ***How does each option set perform along various attributes?***

Since the option sets are exhaustively combined in the symmetric data set, cross-sectional analysis by option set can be done. This reveals overall performance trends. Box plots, such as those in Figure 6-13, are a quick way to review the data.

Figure 6-13: Range of Total Costs for Each Demand-Side Option Set
(144 Scenarios for each of 15 Option Sets)



In this New England data sample, the level of investment in demand-side programs, and the energy reductions achieved, increase (more or less) as one goes from option sets 'A' to 'O'. The graph above shows that increased demand-side investments lead to lower total electric service costs, on average.

3.b.iii How consistent is the performance of each option set?

The consistency across possible futures of any trends revealed may be checked using Friedman's test statistic or other similar non-parametric summary statistics.

Whether the trend shown in the set of box plots above is consistent across all scenarios in the sample needs to be confirmed using future-specific data. Graphical analysis of option sets and strategies on a future-by-future basis is intellectually rewarding, it is also quite time-consuming. Therefore, an initial consistency check should be done statistically, using Friedman's test statistic or Kendall's coefficient of concordance, for example. An application of Friedman's test statistic to the New England project's demand-side option sets is presented below.

We want to test the consistency with which increased DSM efforts lead to reduced total electric service costs, across 36 possible futures and 4 supply option sets, for a total of 144 cases. Do the 15 demand-side option sets (A-O) achieve consistent ranks along the attribute of total cost for all these cases? The hypothesis (H_0) that we hope to disprove is that the rankings are effectively random; if we can disprove this then we can accept the hypothesis (H_1) that some consistency exists.

The first step in this consistency check is to divide the data set into 144 bins representing the 36 possible futures and the 4 supply option sets within each future. This will give us a unique value of the attribute (total cost) for each demand-side option set in the bin. Then we need to rank each of the demand-side option sets in each bin along the total cost attribute. We use ranks instead of actual dollar values because we are interested in the relative, not absolute performance of the demand-side option sets across the various cases. Visual inspection of these ranks provides an impressionistic consistency check, as can be seen in Table 6-3.

Table 6-3: Consistency of Demand-Side Option Set Ranks

Total Cost of Electric Service -- Attribute Values for Demand-Side Option Sets across 144 Cases

Demand-Side	Case: Future & Supply Option Set										..to 144th
Option Set	HDFB-0	HDFB-1	HDFB-2	HDFB-3	HDFC-0	HDFC-1	HDFC-2	HDFC-3	HDFE-0	HDFE-1	Case....
A	147,841	148,4661	9,005	150,687	147,964	148,589	149,128	150,809	148,0871	8,712	....
B	145,520	146,2721	6,873	148,648	146,078	146,830	147,432	149,206	146,6361	7,389	....
C	144,980	145,7741	6,418	147,764	145,717	146,511	147,155	148,501	146,4531	7,247	....
D	144,906	145,6871	6,270	147,874	146,592	147,373	147,956	149,560	148,2781	9,059	....
E	142,722	143,6051	4,364	145,463	143,894	144,777	145,536	146,635	145,0661	5,949	....
F	142,782	143,2451	4,202	144,961	144,694	145,157	146,114	146,874	146,6061	7,070	....
G	140,469	140,9431	2,118	142,399	142,816	143,291	144,466	144,747	145,1641	5,638	....
H	143,487	143,8501	4,926	145,174	145,013	145,376	146,451	146,700	146,5391	6,901	....
I	141,192	141,5601	2,702	142,582	143,153	143,521	144,663	144,543	145,1141	5,482	....
J	140,487	140,8881	1,809	141,556	142,626	143,027	143,948	143,695	144,7661	5,166	....
K	138,167	138,7611	9,549	139,055	140,742	141,336	142,124	141,629	143,3161	3,910	....
L	140,335	141,1191	1,683	141,087	143,424	144,208	144,772	144,176	146,5131	7,297	....
M	138,145	138,5531	9,508	138,828	141,460	141,868	142,823	142,143	144,7751	5,183	....
N	138,054	138,6261	9,410	138,727	141,579	142,151	142,934	142,251	145,1031	5,675	....
O	135,795	136,4191	6,276	136,375	139,545	140,169	140,026	140,125	143,2951	3,920	....

Total Cost of Electric Service – Ranks of Demand-Side Option Sets across 144 Cases

Demand-Side	Case: Future & Supply Option Set										..to 144th
Option Set	HDFB-0	HDFB-1	HDFB-2	HDFB-3	HDFC-0	HDFC-1	HDFC-2	HDFC-3	HDFE-0	HDFE-1	Case....
A	15	15	15	15	15	15	15	15	14	14	....
B	14	14	14	14	13	13	13	13	13	13	....
C	13	13	13	12	12	12	12	12	9	11	....
D	12	12	12	13	14	14	14	14	15	15	....
E	9	10	10	11	9	9	9	9	5	8	....
F	10	9	9	9	10	10	10	11	12	10	....
G	6	6	7	7	6	6	6	8	8	6	....
H	11	11	11	10	11	11	11	10	11	9	....
I	8	8	8	8	7	7	7	7	7	5	....
J	7	5	6	6	5	5	5	5	3	3	....
K	4	4	4	4	2	2	2	2	2	1	....
L	5	7	5	5	8	8	8	6	10	12	....
M	3	2	3	3	3	3	3	3	4	4	....
N	2	3	2	2	4	4	4	4	6	7	....
O	1	1	1	1	1	1	1	1	1	2	....

The Friedman test statistic (using Neave's formulation) provides a more formal consistency check. It is, more or less, a non-parametric analogue to a Chi-square test, and is defined as follows (Sprent, 1989, pg. 124):

$$T_1 = b\,(t-1)\,(S_t^2 - C) \,/\, (S_r^2 - C)$$

where b = number of cases (36 futures * 4 supply option sets = 144)
t = number of items (15 demand-side option sets)
i = one of 1,...t items (1,...15 demand-side option sets)
j = one of 1,...b cases (1,...144 futures/supply option sets)

x_{ij} = measured impact along attribute x for item i in case j
r_{ij} = rank along attribute x of item i in case j
s_i = sum of ranks r_i of strategy i across all cases j = 1,...b
S_r^2 = uncorrected total sum of squares = $\Sigma_{i,j} r_{ij}^2$
S_t^2 = uncorrected sum of squares between item ranks = $\Sigma_i (s_i^2)/b$
C = correction factor = $1/4\ (b)\ (t)\ (t+1)^2$

A standard statistical package will calculate the Friedman test statistic given rank data such as that presented above. For this example, the Friedman test statistic $T_1 = 1444.47$. Assuming a Chi-square distribution with t-1 (15-1=14) degrees of freedom for T_1 (Sprent, 1989, pg. 124), the critical value at the 99.5% confidence level is 31.32 (Pindyck & Rubinfeld, 1981, pg. 607), which is dramatically exceeded given that 1444.47 >> 31.32. Thus we can forthrightly reject the null hypothesis of no consistency, and instead trust that the total cost-based rankings of demand-side option sets are fairly consistent across futures and supply option sets.

Having statistically confirmed that the trend shown in Figure 6-13 is consistent across cases, we can now simplify the presentation of data to the advisory group. The average values may be plotted, rather than all of the cases, or a series of intimidating box plots, in order to convey the message that increasing levels of demand-side effort reduce the total cost of electric service. Such a graph is shown in Figure 6-14.

Similar analysis for other attributes allows us to summarize the performance of the demand-side option sets in just a few graphs, as follows in Figures 6-14, 6-15, and 6-16. Even these simplified graphics improve our understanding of important nuances. For example, it is clear that some demand-side option sets (E, G, K and O) are particularly effective at reducing total costs and CO_2 emissions. Further, those demand-side option sets that are best at reducing new site MW (H, J, K and M) are the worst at reducing SO_2 emissions.

Figure 6-14: Total Cost of Electric Service -- Average by DSM Option Set
Source: Andrews et al 1990

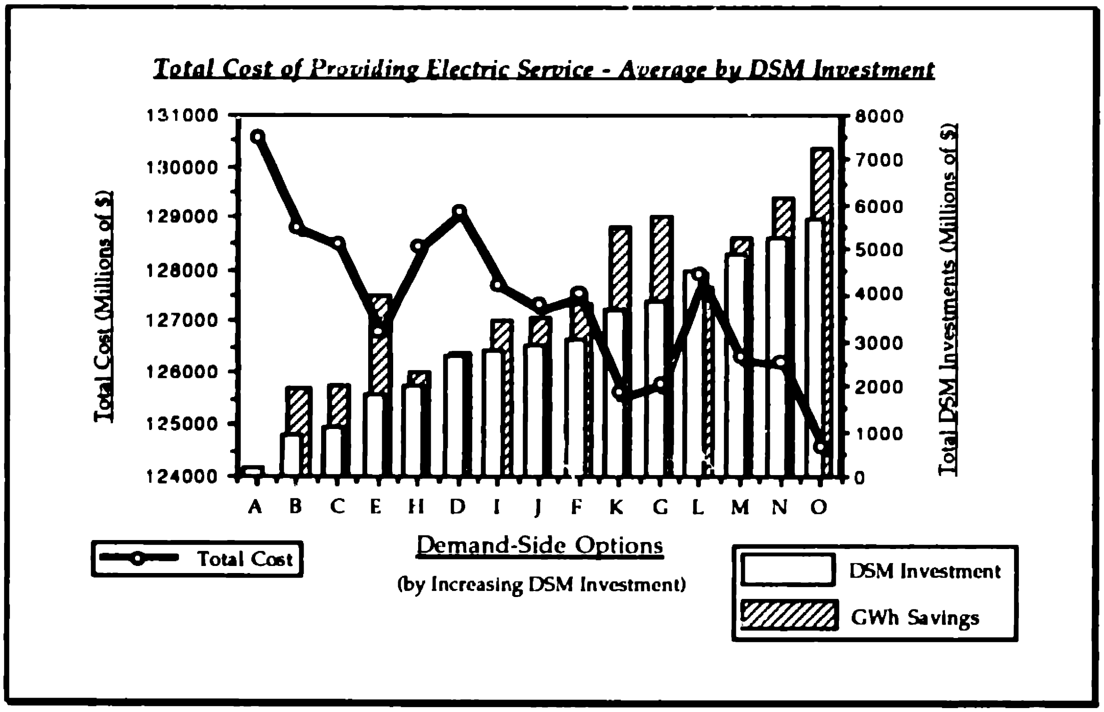


Figure 6-15: Total New Capacity on New Sites -- Average by DSM Option Set
Source: Andrews et al 1990

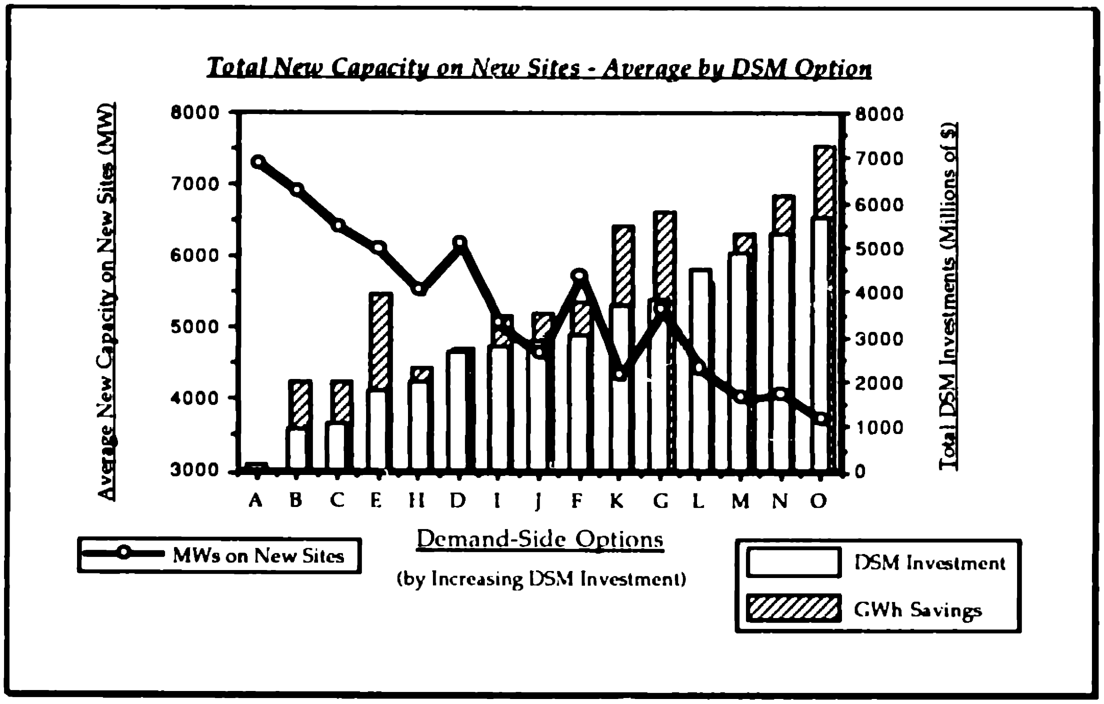
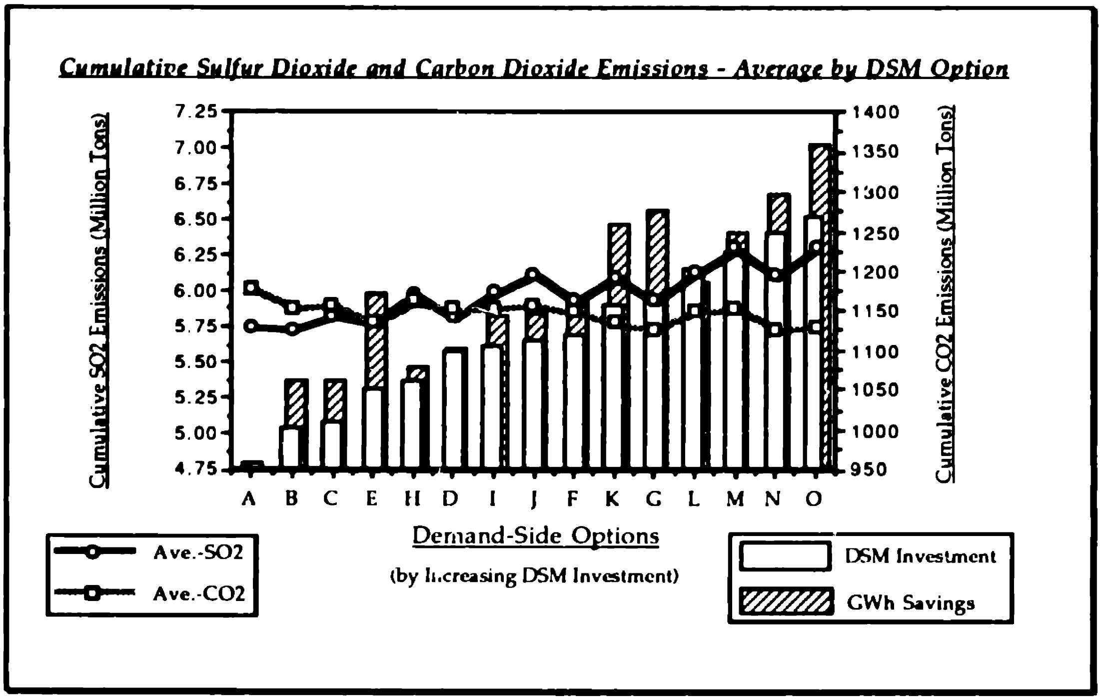
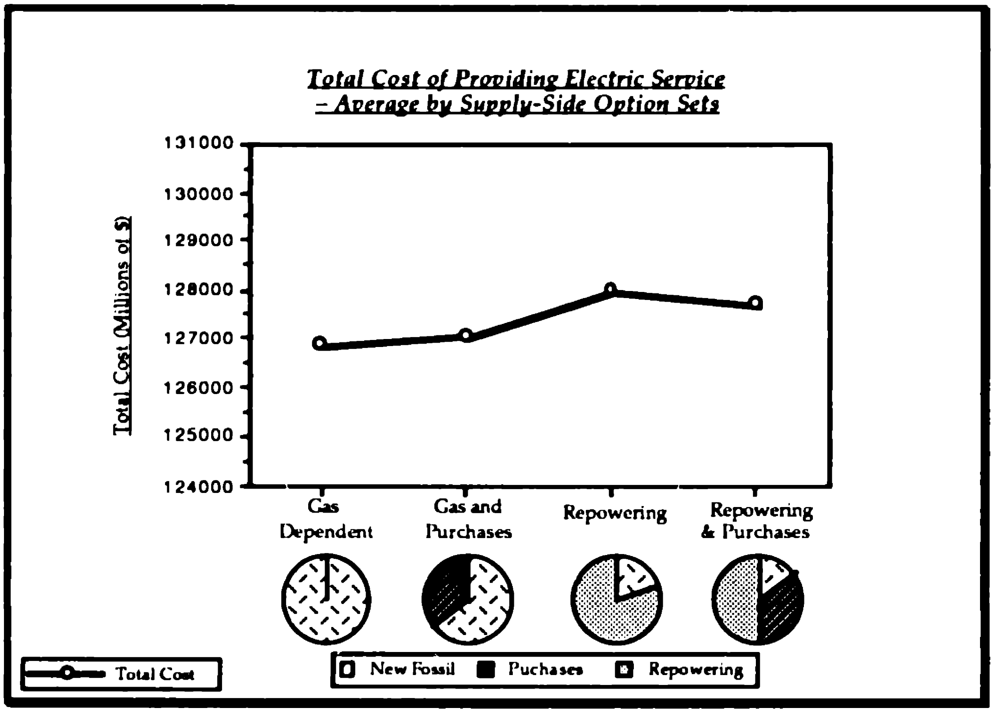


Figure 6-16: Cumulative SO_2 and CO_2 Emissions -- Average by DSM Opt. Set
Source: Andrews et al 1990



The scenarios can also be sectioned by supply option set, and then evaluated for trends and consistency in performance. The environmental impacts revealed by such an analysis are summarized in Figures 6-17, 6-18, and 6-19. Unlike those for demand-side option sets, cross-sections of the data by supply option set show no pronounced trend for the total cost attribute. The medians and ranges for different supply option sets are quite similar to one another. Close scrutiny reveals a slight but consistent trend (across futures and demand-side option sets) of increasing total cost from gas-dependent, gas-plus-power purchases, repowering-plus-purchases, to repowering. However, the medians differ from one another by less than one percent, and for decision making purposes the total costs of these supply option sets appear to be nearly equivalent. This was partly a function of always targeting the same number of megawatts on the supply-side (unlike the demand-side), of similar plant sizes across technologies, of low operating costs (relative to existing capacity) offsetting increased capital costs, and of no supply-side capital cost uncertainty being modeled (whereas two demand-side uncertainties were analyzed). This emphasis reflected the current interest of the advisory group members in demand-side activities.

Figure 6-17: Total Costs -- Average by Supply Option Set
Source: Connors and Andrews, 1990



Trends are much more dramatic for the environmental attributes. Repowering, and to a lesser degree power purchases, reduce new site needs compared to the gas-dependent strategy. Repowering is also extremely effective at reducing SO_2 emissions. By contrast, power purchases, because of their non-fossil generation, are most effective for reducing CO_2 emissions.

Figure 6-18: Total New Capacity on New Sites -- Average by Supply Option Set
Source: Connors and Andrews, 1990

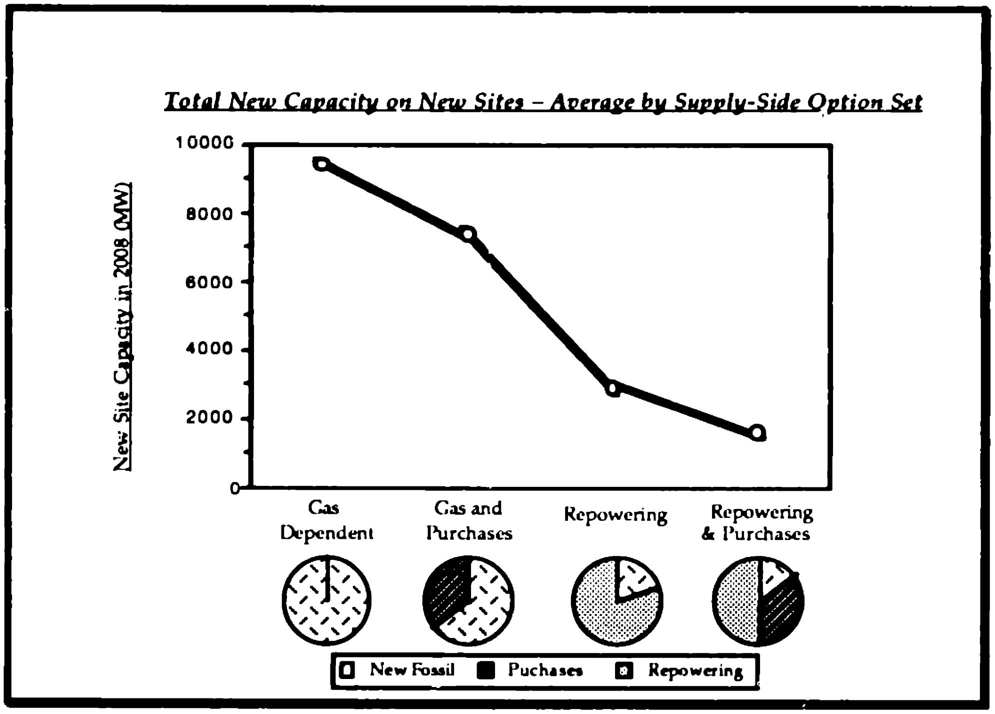
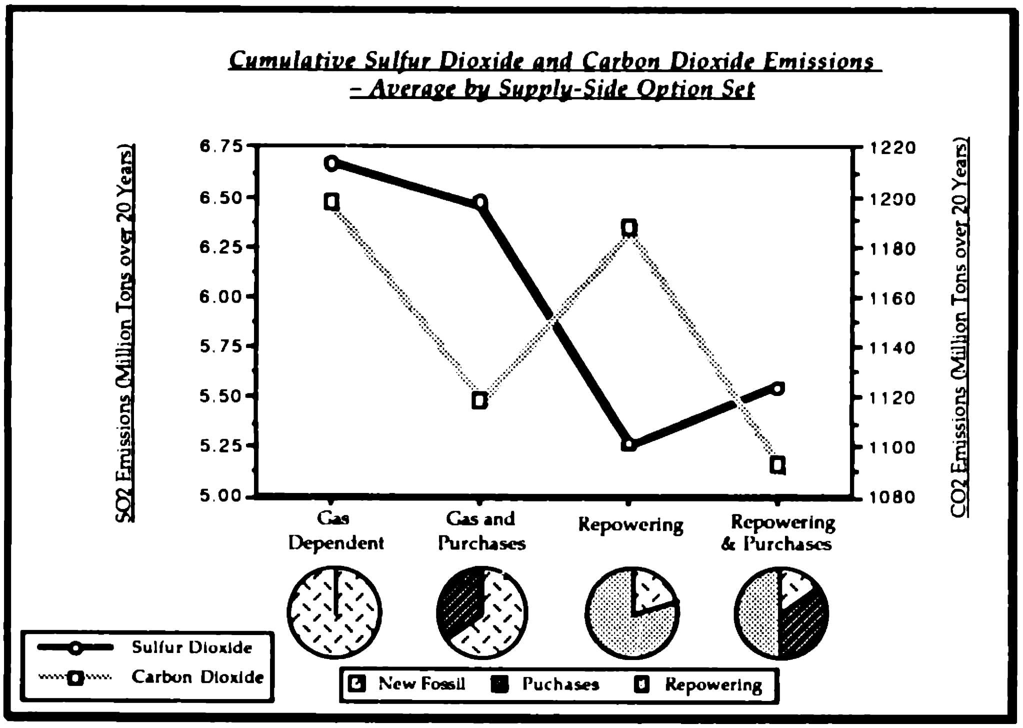


Figure 6-19: Cumulative SO_2 and CO_2 Emissions -- Average by Supply Opt. Set
Source: Connors and Andrews, 1990



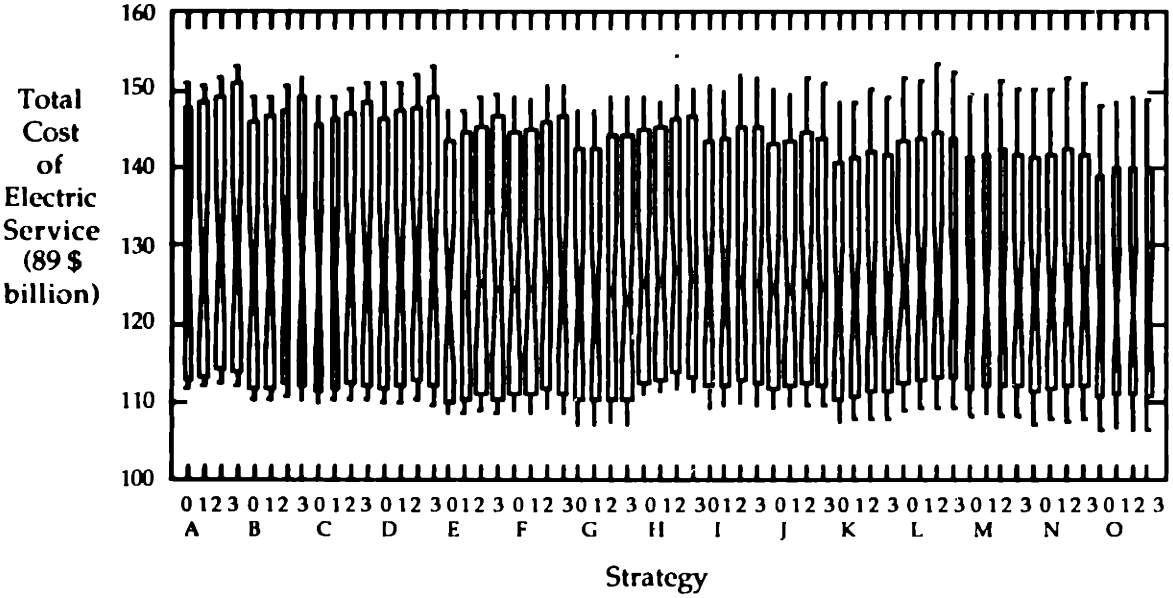
Cross-sectional analysis of the scenario data base by option set reveals a great deal about the characteristics of the different building blocks of strategies. It provides clues for understanding how strategies themselves perform. With this background we are now ready to directly analyze the strategies.

3.b.iv. How does each strategy perform relative to attribute 'A'?'B'?

Slice the data set into strategy-specific cohorts, representing the ranges of outcomes across all futures studied. Look at box plots to spot performance trends.

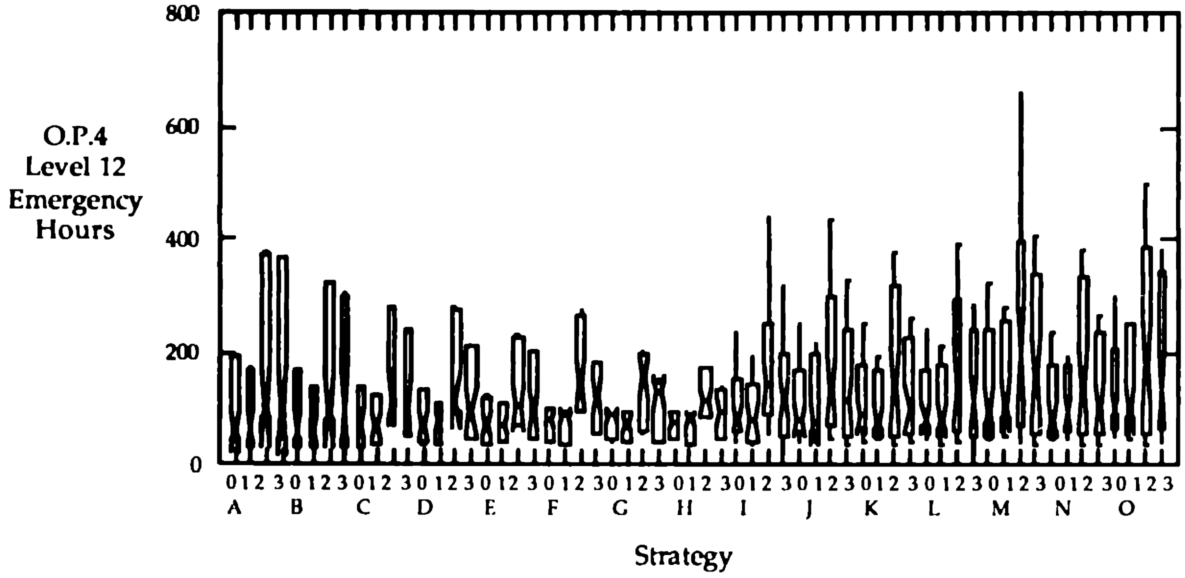
Evaluation of the strategies confirms the same trends identified earlier for option sets. For example, the plot in Figure 6-20 shows that, on average, gas-dependent strategies with high DSM investments (say strategy O0)have the lowest total costs. It also confirms that the demand-side component is more important than the supply component in determining the total cost of a strategy.

Figure 6-20: Range of Total Costs for Each Strategy (across 36 possible futures)



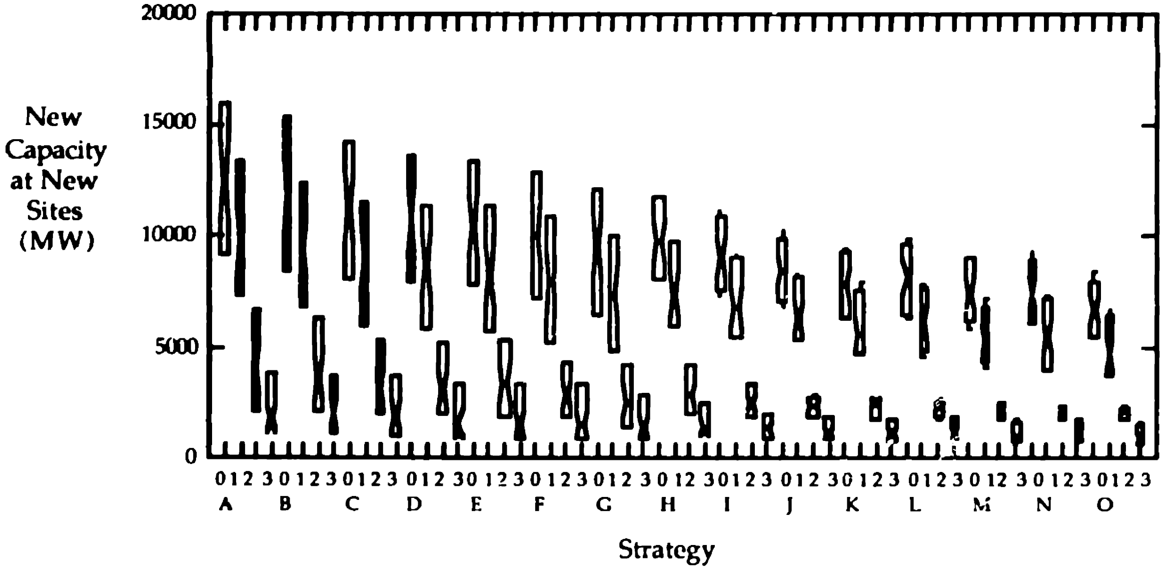
Box plots of O.P. 4 Emergency Hours for each strategy (see Figure 6-21) point out two important planning considerations. First, the repowering-based strategies (_2, _3) have consistently worse reliability problems. This reflects the way they were modeled, with a mandatory one year of down-time for each plant that gets repowered. Second, the demand-side option sets that include both utility programs and other measures (I_ to O_) show a wide range of O.P. 4 hours across possible futures. This reflects the impact of DSM interactions (due to program redundancy), which are modeled to reduce the effectiveness of utility programs below what was planned, thus delaying needed capacity by a year in some possible futures. Strategies with both repowering and high DSM (such as M2 and O2) had the most volatile performance across possible futures. While both of these effects are due to modeling assumptions, they are realistic, and highlight the special care that must be taken when planning to actually use these strategies.

Figure 6-21: Range of O.P. 4 Emergency Hours for Each Strategy
(across 36 possible futures)



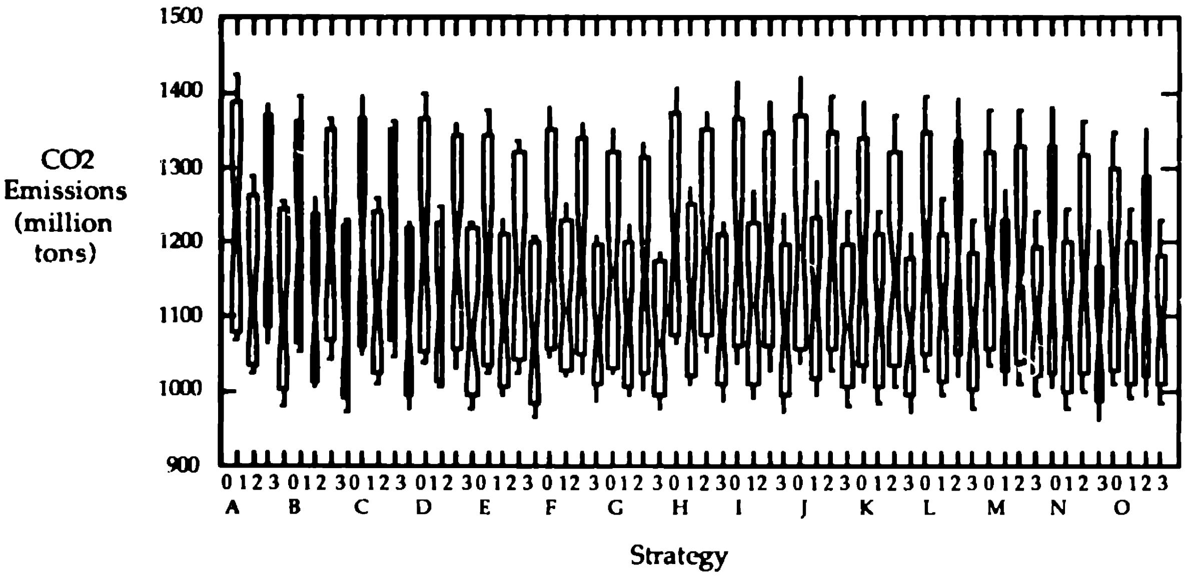
A look at the box plots for New Site MW by strategy (see Figure 6-22) shows that three types of options -- high DSM, repowering, and power purchases -- work in concert to reduce the amount of new capacity needed on New England sites. Each option individually improves the outcome along this attribute; all three together (in strategy O3) provide the greatest benefit.

Figure 6-22: Range of New Capacity at New Sites for Each Strategy (across 36 possible futures)



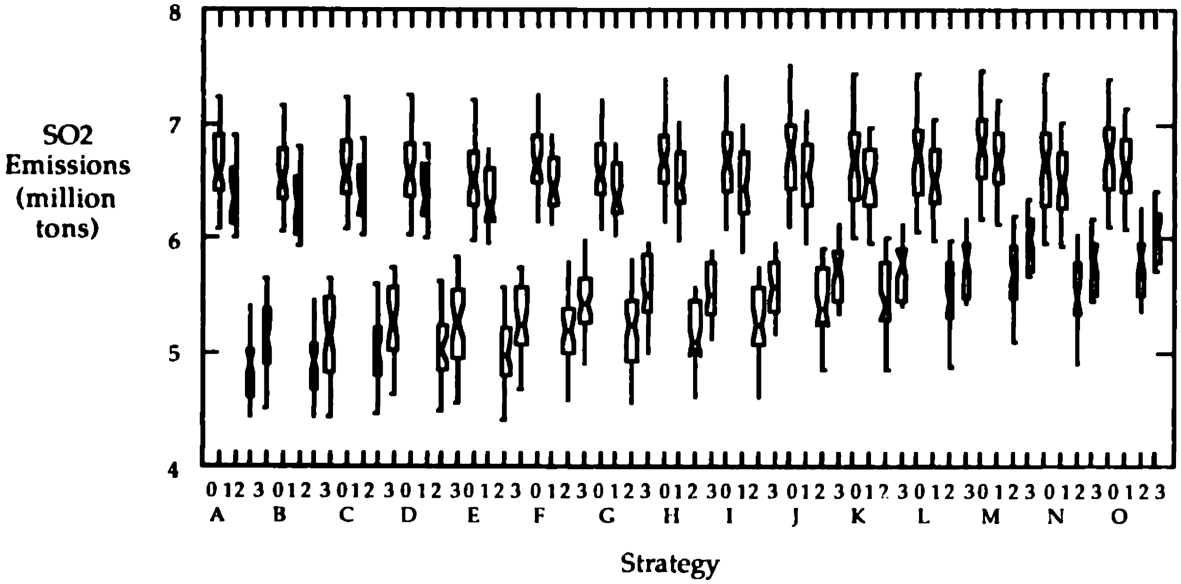
The three options reinforce one another along the carbon dioxide emissions attribute too, but their relative significance differs. As the plots in Figure 6-23 show, power purchases (_1, _3) provide the most dramatic CO_2 reductions, while both repowering and DSM investments contribute more modestly to that goal.

Figure 6-23: Range of Carbon Dioxide Dioxide Emissions for Each Strategy
(across 36 possible futures)



The sulfur dioxide story (see Figure 6-24) is rather more complicated. Power purchases (_1) reduce emissions relative to gas-dependent (_0) supply options, but detract from the effectiveness of repowering to do so (_2 vs. _3). DSM investments detract dramatically from the effectiveness of repowering (A2 vs. O2), but only slightly from gas-dependent supply options (A0 vs. O0), in emissions reductions. In other words, both power purchases and DSM reduce the effectiveness of repowering along this attribute. The options fight instead of reinforce each other.

Figure 6-24: Range of Sulfur Dioxide Emissions for Each Strategy (across 36 possible futures)



The box plots above revealed a great deal about both the absolute and relative performance of the various strategies, and showed the analysts how the options that comprised the strategies interacted with one another in the context of electric power system operations. Most members of the advisory group preferred to look at trends distilled by the analysts rather than confronting these complex box plots themselves. During public presentations, only one "sample" box plot was used to show what was behind the trends shown. Several people did not understand what a box plot was, and explanations had to be provided.

3.b.v. *In general, how do the strategies rank relative to one another along attribute 'A'? 'B'? 'C'?*

Rank the strategies and then calculate their rank sums across all futures.

Table 6-4 ranks the performance of the 60 strategies in the New England study, based on their rank sums across the 36 possible futures. Note that the rankings differ tremendously from attribute to attribute, implying that tough tradeoffs must be made by decision makers confined to this set of alternatives. For example, along the total cost attribute, best-ranked strategies tended to feature high demand-side management investments (G, K, O) and gas-dependence (0, 1). By contrast, the strategies with lowest sulfur dioxide emissions were all low DSM (A, B, C,...) and repowering (2, 3). Even environment-to-environment tradeoffs were revealed, with low-CO_2 strategies differing from low-SO_2 strategies.

Table 6-4: Strategy Rankings

Strategy Rankings -- Rank Sums across 36 Equally-Weighted Futures

Shown in ascending order (best to worst) for each of four attributes.

Total Cost		CO2 Emissions		SO2 Emissions		OP12 Hours	
Strategy	Rank Sum	Strategy	Rank Sum	Strategy	Rank Sum	Strategy	Rank Sum
O0	**160**	**N3**	**117**	**A2**	**66**	**H1**	**333**
O3	**185**	**G3**	**120**	**B2**	**72**	**B1**	**360**
O1	**212**	**E3**	**135**	**E2**	**114**	**E0**	**372**
G1	**273**	**K3**	**162**	**C2**	**162**	**C0**	**408**
K0	**274**	**I3**	**315**	**D2**	**216**	**F1**	**423**
O2	**294**	**F3**	**318**	**A3**	**258**	**C1**	**453**
G0	**298**	**B3**	**324**	**B3**	**270**	**D0**	**483**
K1	**335**	**C3**	**357**	**H2**	**288**	**D1**	**486**
K3	**472**	**D3**	**369**	**I2**	**390**	**F0**	**510**
E0	**502**	**L3**	**375**	**F2**	**402**	**G1**	**516**
G3	531	O3	396	G2	411	E1	528
N0	547	J3	444	C3	441	G0	570
K2	604	H3	450	E3	468	H0	600
E1	610	N1	474	D3	477	I1	606
N1	654	G1	492	J2	528	A1	621
M0	658	E1	543	K2	573	B0	738
M1	694	K1	588	L2	624	A0	768
G2	695	A3	642	H3	654	L1	843
M3	746	O1	666	N2	678	I0	867
N3	794	M3	666	F3	696	J1	870
F1	885	B1	786	I3	711	J0	957
J0	896	L1	786	G3	747	K1	1002
F0	900	I1	798	J3	834	H3	1002
E3	921	D1	801	K3	858	N0	1011
N2	934	J1	921	M2	891	L0	1029
E2	981	F1	948	L3	900	K0	1065
J1	982	C1	966	N3	942	G3	1080
M2	995	H1	1002	O2	945	N1	1122
I0	1071	M1	1029	M3	1044	L3	1125
C0	1124	O2	1041	O3	1080	E3	1128
J3	1155	A1	1140	B1	1161	N3	1140
I1	1158	G2	1140	E1	1200	D3	1152
F3	1211	N2	1185	D1	1308	I3	1155
L0	1247	O0	1218	A1	1317	K3	1155
C1	1250	N0	1257	I1	1317	J3	1197
B0	1269	K2	1281	C1	1353	B3	1212
H0	1296	G0	1296	N1	1392	C3	1293
L1	1346	E2	1362	G1	1404	A3	1308
B1	1369	M2	1410	K1	1416	F3	1323
F2	1374	K0	1455	H1	1431	K2	1341
H1	1397	E0	1521	E0	1443	O1	1434
I3	1401	F2	1533	L1	1515	E2	1437
J2	1413	L2	1605	F1	1542	O0	1446
L3	1469	D2	1608	J1	1548	H2	1446
D0	1499	M0	1629	B0	1599	N2	1446
I2	1598	L0	1695	D0	1665	M0	1458
C3	1609	F0	1758	N0	1698	G2	1491
D1	1614	I2	1776	C0	1731	M3	1521
L2	1618	B2	1797	G0	1746	B2	1524
H3	1633	J2	1800	A0	1779	L2	1527
C2	**1684**	**C2**	**1803**	**O1**	**1824**	**M1**	**1542**
B3	**1745**	**H2**	**1821**	**K0**	**1830**	**O2**	**1587**
D3	**1763**	**D0**	**1824**	**I0**	**1893**	**O3**	**1626**
B2	**1786**	**I0**	**1884**	**L0**	**1926**	**A2**	**1689**
H2	**1804**	**J0**	**1917**	**F0**	**1941**	**D2**	**1692**
A0	**1894**	**B0**	**1944**	**M1**	**1959**	**J2**	**1701**
A1	**1919**	**C0**	**1959**	**H0**	**1992**	**C2**	**1704**
D2	**1923**	**H0**	**2019**	**O0**	**2010**	**F2**	**1779**
A3	**2098**	**A2**	**2061**	**J0**	**2058**	**M2**	**1821**
A2	**2111**	**A0**	**2151**	**M0**	**2142**	**I2**	**1857**

3.b.vi. *How consistent are strategy rankings across different futures?*

As was done with demand-side option sets above, rank the strategies within each future, first for one attribute, then the next. Measure consistency with the Friedman test statistic or a similar technique.

Friedman test statistics for the four attributes shown above indicate that there is a fair amount of consistency in ranks across futures (see Table 6-5).

Table 6-5: Consistency Tests

Consistency of Ranks for 60 Strategies across 36 Futures
Critical value (Chi-square) with 59 DOF @ 99.5% LOC = 91.95
(Pindyck & Rubinfeld, 1981, pg. 607)

Attribute	Friedman Test Statistic	Reject Null Hypothesis?	Kendall Coefficient of Concordance
Total Cost	1565.05 >> 91.95	Yes	0.737
CO_2 Emissions	1989.89 >> 91.95	Yes	0.937
SO_2 Emissions	2035.40 >> 91.95	Yes	0.958
O.P. 12 Emerg.Hrs.	1054.86 >> 91.95	Yes	0.497

There appears to be a substantial degree of consistency across futures in the ranks of the strategies, for all four attributes. Strategies appear to perform less consistently along the reliability measure, O.P. 4 Emergency Hours, than the others, and more so for SO_2 and CO_2.

3.b.vii. How volatile is the performance of each strategy given uncertainty?

Evaluate the summary statistics for each strategy -- in particular, rank them by the sizes of their variances. Use these to compare the volatility of each strategy's performance on attribute 'A', 'B' and so on. Review the box plots for evidence of volatility or robustness.

Table 6-6 below shows the sixty New England strategies sorted in order of increasing variance, for four different attributes. For total cost, it appears that the lowest-cost strategies (high-DSM, such as K_, O_ as identified in Table 6-4) are also the least volatile ones, but that the difference in volatility between best and worst strategies is not very large. For carbon dioxide emissions, volatility also increases with average emissions levels, but the difference between the best and worst strategies is greater. The strategy variances for sulfur dioxide emissions behave quite differently from the strategy averages. Strategies with repowering and power purchases (_3) have the lowest SO_2 variances, while those that are gas-dependent (_0) have the highest. Finally, the variances for O.P. 4 Level 12 Emergency Hours are dramatically different between the best and worst strategies. The least volatile ones (C-H,0-1) also enjoy the lowest average levels of emergency hours.

Table 6-6: Strategy Volatility

Strategy Volatility -- Variances across 36 Equally-Weighted Futures

Shown in ascending order (least to most) for each of four attributes.

Total Cost		CO2 Emissions		SO2 Emissions		OP12 Hours	
Strategy	Variance	Strategy	Variance	Strategy	Variance	Strategy	Variance
O0	**1.94E+08**	**G3**	**6,812**	**M3**	**0.059**	**H0**	**430.629**
O1	**1.95E+08**	**M3**	**7,165**	**O3**	**0.059**	**G0**	**463.457**
M1	**2.00E+08**	**O3**	**7,257**	**K3**	**0.062**	**G1**	**487.429**
M0	**2.00E+08**	**F3**	**7,466**	**H3**	**0.065**	**H1**	**563.229**
O2	**2.00E+08**	**K3**	**7,629**	**N3**	**0.065**	**F1**	**602.886**
H1	**2.01E+08**	**N3**	**7,660**	**L3**	**0.066**	**F0**	**616.457**
O3	**2.01E+08**	**G1**	**7,749**	**J3**	**0.067**	**E1**	**747.229**
K1	**2.02E+08**	**L3**	**7,760**	**F1**	**0.069**	**D1**	**869.971**
K0	**2.03E+08**	**F1**	**8,233**	**I3**	**0.069**	**C1**	**1281.6**
K3	**2.04E+08**	**J3**	**8,295**	**G1**	**0.070**	**E0**	**1296.57**
H0	2.06E+08	O1	8,346	D1	0.077	H2	1329.486
J1	2.06E+08	H3	8,451	E1	0.077	H3	1509.743
M3	2.08E+08	E1	8,560	C1	0.078	D0	1752.829
N1	2.08E+08	I3	8,850	O2	0.083	C0	1902.314
I1	2.09E+08	M1	8,907	A1	0.088	B1	2064.229
N0	2.09E+08	K1	8,988	B1	0.089	G3	2267.886
J0	2.09E+08	L1	9,151	A2	0.094	F3	2853.743
N3	2.10E+08	D1	9,155	H2	0.100	B0	2983.429
H2	2.11E+08	E3	9,233	O1	0.104	K1	3095.05
I0	2.13E+08	N1	9,242	G3	0.105	I1	3170.629
K2	2.13E+08	C1	9,431	K1	0.105	A1	3192
G0	2.13E+08	D3	9,795	L1	0.109	N1	3216.593
M2	2.14E+08	C3	10,009	M1	0.110	G2	3558.657
L0	2.14E+08	B1	10,105	B2	0.111	L1	4135.514
J3	2.14E+08	I1	10,221	N1	0.111	A0	4391.914
L1	2.14E+08	H1	10,472	H1	0.114	I0	4466.743
G1	2.16E+08	B3	10,533	I1	0.117	E3	4555.543
J2	2.18E+08	J1	10,655	M2	0.117	N0	4811.221
L3	2.18E+08	A1	10,784	J2	0.118	D3	4862.543
H3	2.18E+08	A3	11,536	F3	0.121	E2	4873.943
F0	2.19E+08	E2	15,098	K2	0.121	J1	4890.657
N2	2.21E+08	O0	15,238	E3	0.122	L0	4927.543
I2	2.22E+08	H2	15,307	F0	0.124	J0	5492.314
F1	2.22E+08	C2	15,412	L2	0.125	K0	5602.943
E0	2.22E+08	M0	15,466	B0	0.128	F2	5718.057
I3	2.23E+08	A2	15,737	G0	0.129	C3	6393.943
L2	2.25E+08	B2	15,905	J1	0.129	O1	6711.657
E1	2.26E+08	O2	16,040	C2	0.131	D2	7014.086
C0	2.27E+08	D2	16,169	D2	0.131	C2	7167.914
G2	2.28E+08	G0	16,407	I2	0.132	K3	7369.429
B0	2.30E+08	G2	16,642	N2	0.133	O0	7539.943
C1	2.30E+08	F2	16,949	A3	0.136	N3	7801.457
F2	2.31E+08	F0	16,958	E2	0.136	M1	7837.05
E2	2.31E+08	I2	17,022	C0	0.137	L3	8691.486
B1	2.33E+08	M2	17,330	C3	0.138	I3	9301.514
G3	2.34E+08	J2	17,507	A0	0.140	M0	10175.05
D0	2.34E+08	K2	17,521	F2	0.152	J3	11322.6
C2	2.35E+08	B0	17,525	D0	0.157	B3	12503.57
B2	2.35E+08	N2	17,616	E0	0.158	B2	12952.8
D1	2.36E+08	L2	17,921	M0	0.161	L2	16289.89
A2	**2.37E+08**	**H0**	**17,932**	**H0**	**0.162**	**K2**	**16778.3**
A1	**2.37E+08**	**C0**	**18,057**	**B3**	**0.163**	**I2**	**17079.9**
A0	**2.37E+08**	**L0**	**18,132**	**G2**	**0.169**	**O3**	**17579.7**
D2	**2.40E+08**	**E0**	**19,004**	**O0**	**0.169**	**N2**	**17801.2**
F3	**2.43E+08**	**A0**	**19,118**	**D3**	**0.170**	**A2**	**18025.6**
E3	**2.49E+08**	**N0**	**19,252**	**I0**	**0.184**	**M3**	**19026.1**
C3	**2.55E+08**	**I0**	**19,329**	**L0**	**0.191**	**J2**	**19418.6**
B3	**2.62E+08**	**K0**	**19,372**	**J0**	**0.204**	**A3**	**20204.2**
A3	**2.64E+08**	**D0**	**19,687**	**K0**	**0.217**	**O2**	**29054.7**
D3	**2.69E+08**	**J0**	**19,956**	**N0**	**0.220**	**M2**	**45878**

3.b.viii. Do different uncertainties affect different strategies?

Compare the relative ranks of the best strategies across all possible futures in the data set. Determine which possible futures affect the performance of these strategies, and identify the underlying uncertainties.

Figures 6-25, 6-26, 6-27, and 6-28 show the future-specific ranks of the three best strategies, and one worst-ranked strategy for each attribute, based on their rank sums across all 36 possible futures. For total cost, the three best strategies (all DSM option set "O") track very closely with one another. They suffer spikes, representing worsened ranks, in futures that include cost overruns on DSM programs (___E). The sizes of these spikes increase in futures with low economic growth (L___), and are worst when DSM program interactions (_S__) are also present. Thus the worst possible future for the best-ranked option is LSFE, where its future-specific rank drops to 23rd, compared to its 1st place average across all 36 futures. Parties who think that this future is particularly likely will not favor strategy O0 as much as others might.

The ranks of the three best strategies for reducing sulfur dioxide emissions are much more stable across possible futures than those for total cost. As can be seen in Figure 6-26, the three best strategies for reducing SO_2 emissions all stay within the top five for every possible future modeled. The only flipping that occurs is under high economic growth, when first-overall ranked strategy A2 drops to third place and third-overall ranked strategy E2 moves to first place.

Figure 6-25: Total Cost of Electric Service -- Strategy Ranks

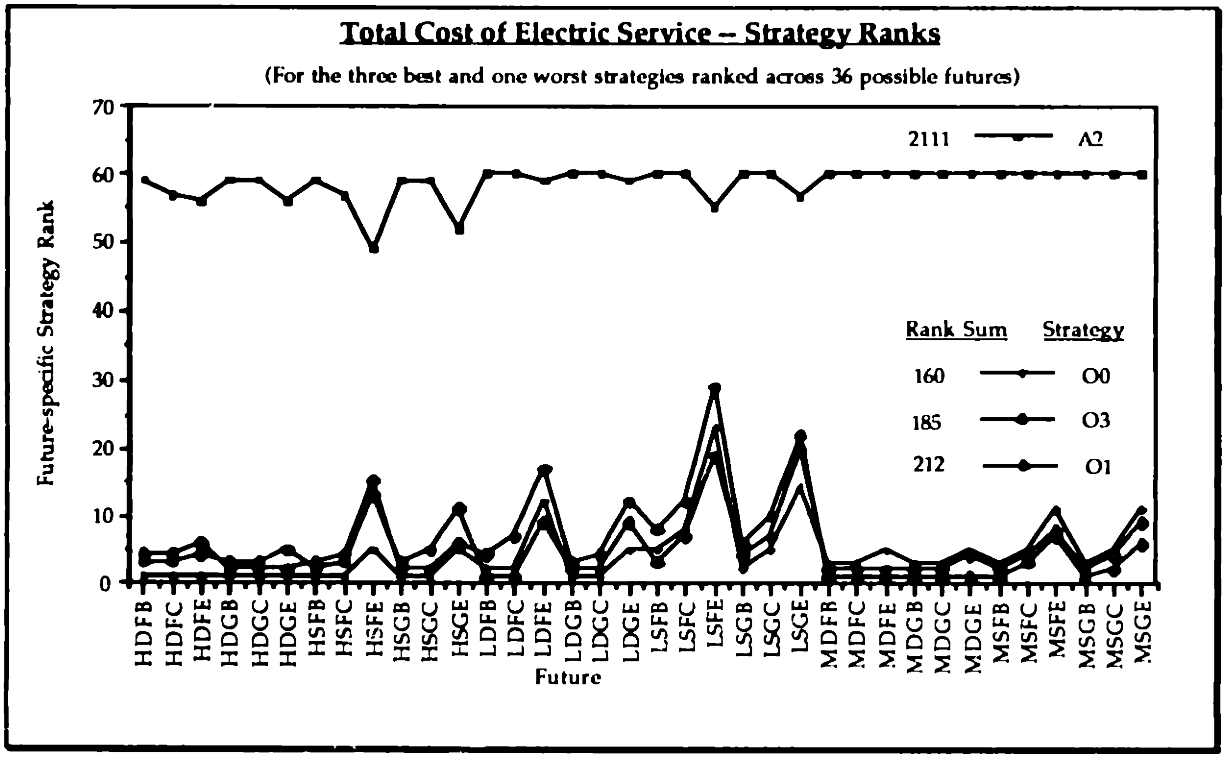
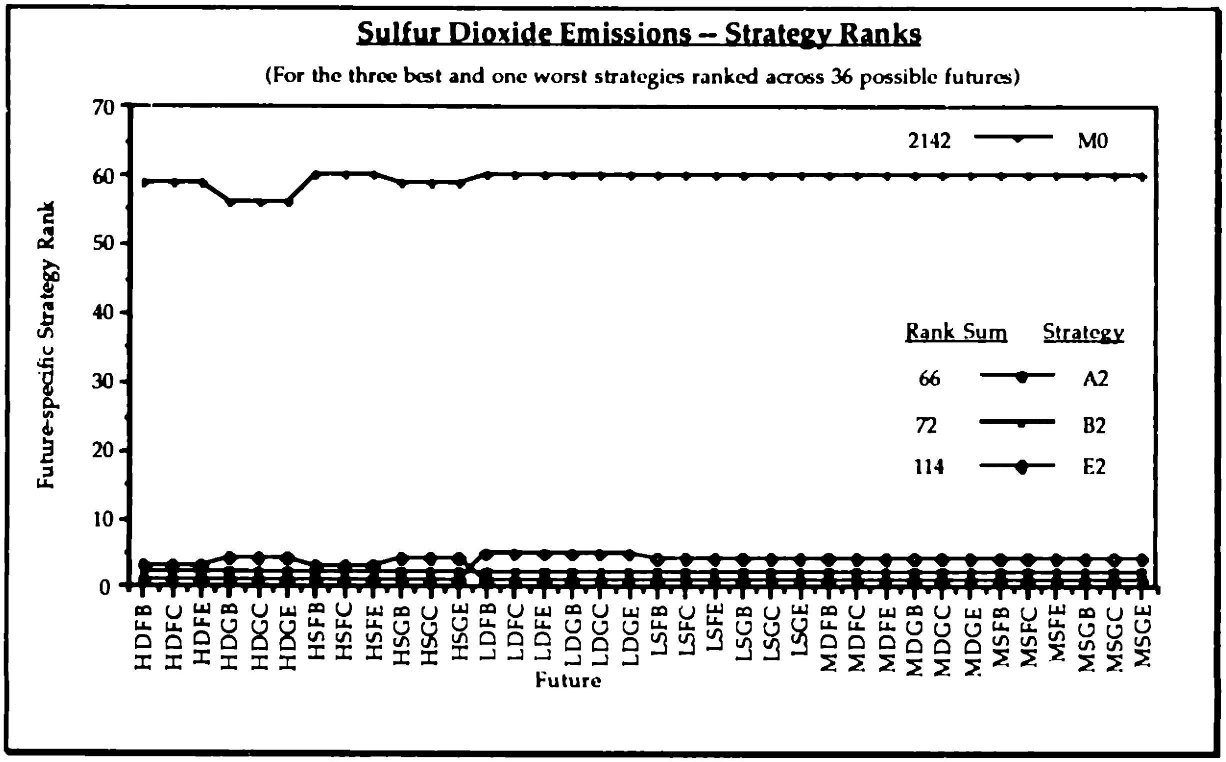
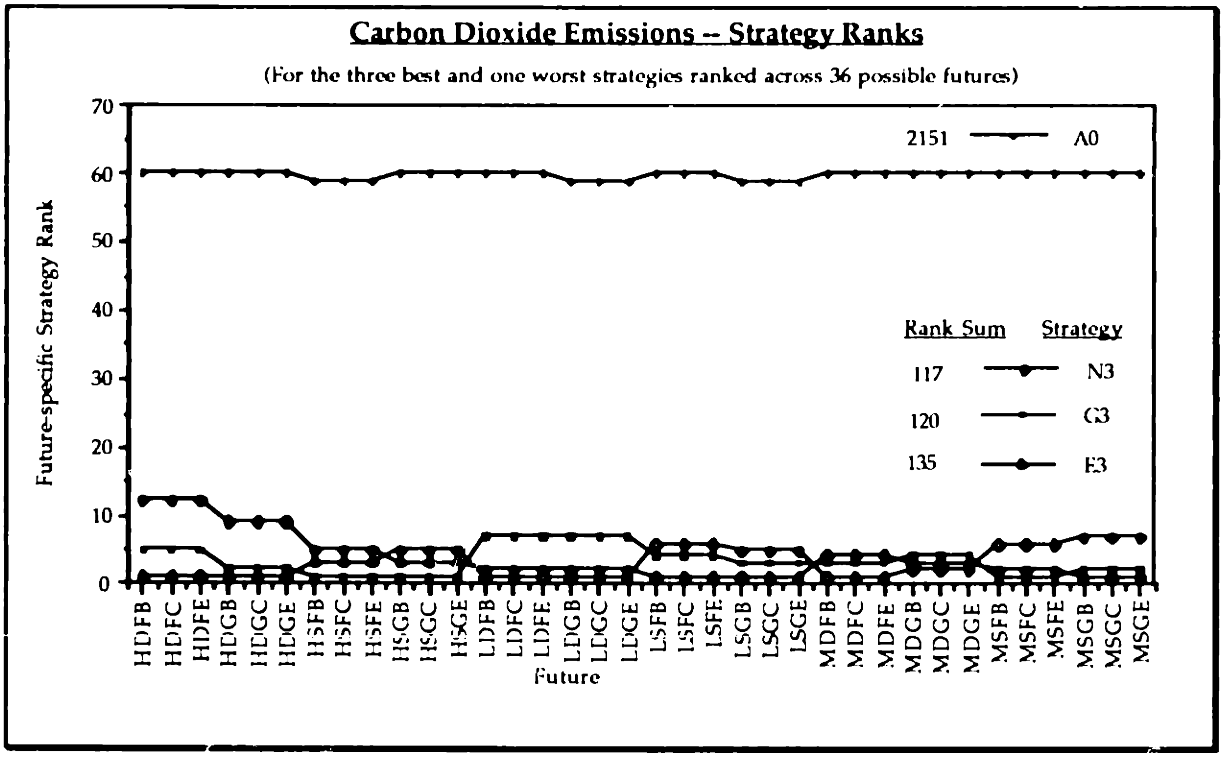


Figure 6-26: Sulfur Dioxide Emissions -- Strategy Ranks



The best-overall ranked strategies for CO_2 reduction reveal slightly more volatility. As Figure 6-27 shows, the first-overall ranked strategy drops as far as seventh place when confronted with DSM program interactions (_S__) and high gas prices (__G_) under medium economic growth (M___). The third-overall ranked strategy drops as far as twelfth place in certain possible futures.

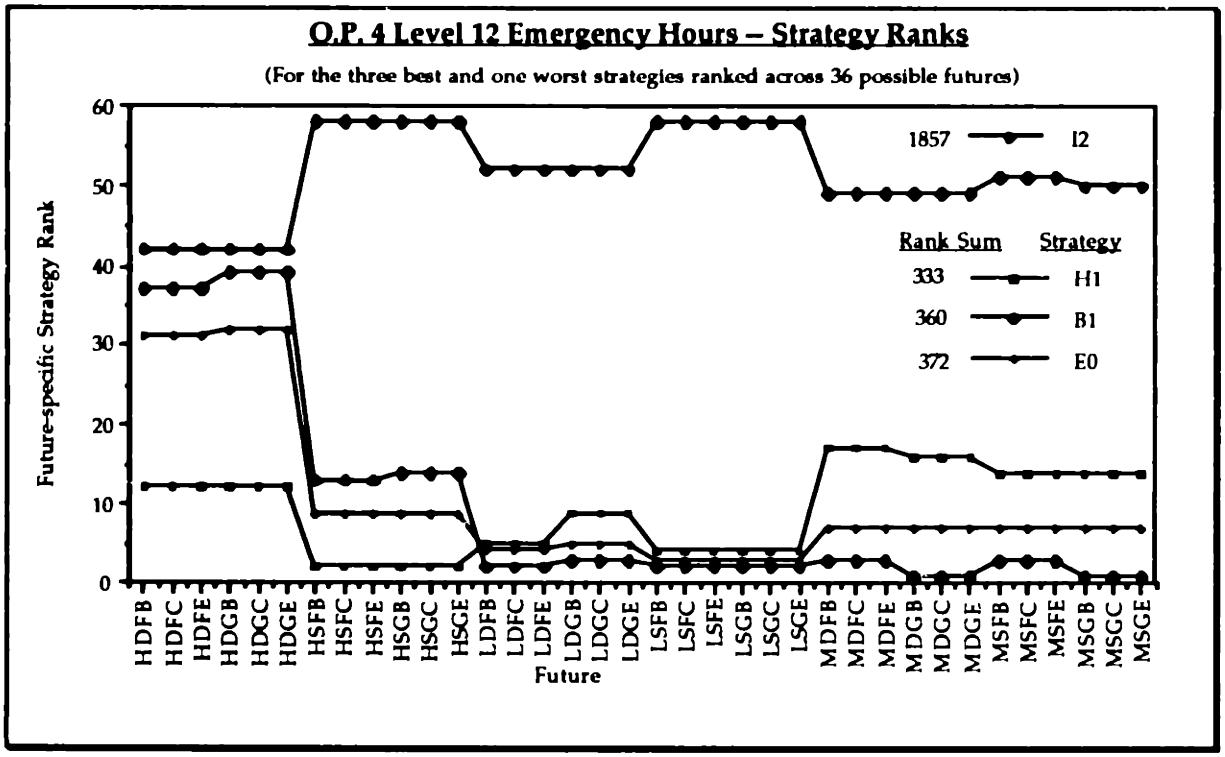
Figure 6-27: Carbon Dioxide Emissions -- Strategy Ranks



The best strategies for reliability reveal dramatic volatility regarding their ranks along O.P. 4 Level 12 Emergency Hours. The first-overall ranked strategy drops as low as 17th place in a set of possible futures that many parties might consider to be among the most likely -- medium economic growth, base fuel prices, no DSM program interactions, and on-budget DSM programs.

The second-overall ranked strategy drops to 39th place (out of 60) in several of the high economic growth futures.

Figure 6-28: O.P. 4 Level 12 Emergency Hours -- Strategy Ranks



Analysis of this sort shows us the potential weaknesses of strategies, revealing information that is masked by the aggregate statistical measures. Once the best-overall strategies (across all possible futures modeled) for each attribute are identified, they warrant more detailed examination across individual futures.

This section has focused on univariate analysis of strategies, one attribute at a time. In the next section we will consider multiple attributes, which are the actual basis for most of the difficult decisions that must be made. The univariate analysis has taught us a great deal about both the behavior of the system under uncertainty, and the performance of the various strategies and their components.

Step 3.c. Observe the performance of strategies -- consider multiple attributes

Multi-attribute analysis shows us the tradeoffs that must be weighed in making planning decisions. By contrasting the relative performance of strategies along several attributes we begin to understand their strengths and weaknesses, as well as our own overall preferences. We can also gain a sense of how the component options that make up strategies interact, i.e., whether they work with or against one another in a general sense. It is crucial to develop an understanding of these interactions when trying to invent a better class of strategies.

3.c.i. How does each strategy perform for different attribute pairings?

Evaluate the performance of strategies in two-dimensional space using a series of scatter plots. Begin with the highest priority attributes, and plot the median values (across all futures modeled) for each strategy. Identify clusters/trends by option set, and characterize their interactions.

The main vehicle for sharing results with the large group of participants in an open planning process is graphical analysis, which is most effective when limited to two attributes at a time. Since the data set includes many attributes, it is useful to start with the attribute pairs of greatest interest to the participants, i.e., those assigned the highest priority in Step One of the open planning process (see Chapter Five). For New England, these were cost, sulfur dioxide emissions, carbon dioxide emissions, and reliability.

Before poring through scatter plots of various attribute pairings for each of 36 futures, we can look for trends by plotting the median values across all 36 futures of each strategy's performance. Once we understand the trends that are revealed by the median data, we can check the robustness of the conclusions by looking at individual futures.

In reading a scatter plot, certain rules guide our preferences. All of the primary attributes – costs, emissions, danger hours – are things we desire to minimize. Therefore, the lower left-hand corner of the plot is our preferred position. Strategies that have low costs and low emissions are preferable to those having high costs and high emissions, of course. Likewise, those that either produce fewer emissions for the same cost, or have a lower cost with the same emissions are also always preferred. Choices among strategies involving tradeoffs, such as lower emissions but higher cost, depend upon value judgements that weigh preferences between cost and emissions reduction, and will differ from person to person. The details of eliciting stakeholder values and developing decision rules are discussed in the next chapter. At this stage of the analysis, only the concept of simple dominance, or "closer to the origin is better" is needed to interpret the scatter plots.

Figure 6-29 shows cost vs. CO_2 emissions, and reveals a number of important points about the option sets comprising various strategies. First, the primary clustering is based on the amount of power purchases in the strategy. Power purchase strategies A1, B1,...O1 and A3, B3, ...O3 have lower CO_2 emissions and equivalent costs than those without this component (A0, B0,...O0 and A2, B2,...O2). For these two attributes, power purchases seem to be an important piece of any winning strategy because of their large portion of cost-effective non-fossil generation (hydro and nuclear).

This same plot shows that high levels of demand-side management also seem desirable, that is, strategies O0, O1, O2, and O3 are lower in cost than strategies A0, A1, A2, and A3. However, there is a complication, because although high-DSM strategy O0 dominates lower-DSM strategy G0, strategy

O3 does not dominate G3. Without power purchases, increasing levels of demand-side activity reduce both cost and CO_2 emissions, but with power purchases the DSM investments help to a point, but then start to fight the power purchase option. DSM effort and power purchases work together in reducing CO_2 emissions until strategy G3 is reached; additional DSM still reduces costs, but leads to increased CO_2 emissions.

Figure 6-30 keeps cost on the vertical axis but puts SO_2 emissions on the horizontal axis. This time the major clustering of strategies depends on whether or not they include repowering. Those with repowering (A2 and A3, for example) have dramatically lower SO_2 emissions and slightly increased costs compared to non-repowering strategies such A0 and A1. As before, increasing demand-side efforts decrease costs. For strategies without repowering, increased DSM initially helps to reduce SO_2 emissions, but larger amounts (beyond, say, option set E) lead to larger cumulative SO_2 emissions. In strategies with repowering, increased demand-side efforts work consistently against those on the supply side, so that high-DSM option sets such as O3 have larger SO_2 emissions, albeit with lower costs of service.

A third environmental attribute – megawatts of new capacity on new New England sites – serves as a proxy for site-related or "Not In My Back Yard" problems. Although this was not selected as a high-priority attribute by the participants in the June 1989 meeting, it gained interest in later meetings to ensure that local as well as regional and global environmental impacts were understood. Figure 6-31 shows cost vs. new site megawatts. The major clustering is determined by the presence of repowering in the strategies, and this time, all of the options work with, instead of against one another. Repowering, power purchases, and DSM all reduce the amount of new site megawatts required.

Figure 6-29: Scatter Plot of Cost vs. CO_2 -- Average Values
Source: Connors and Andrews, 1990

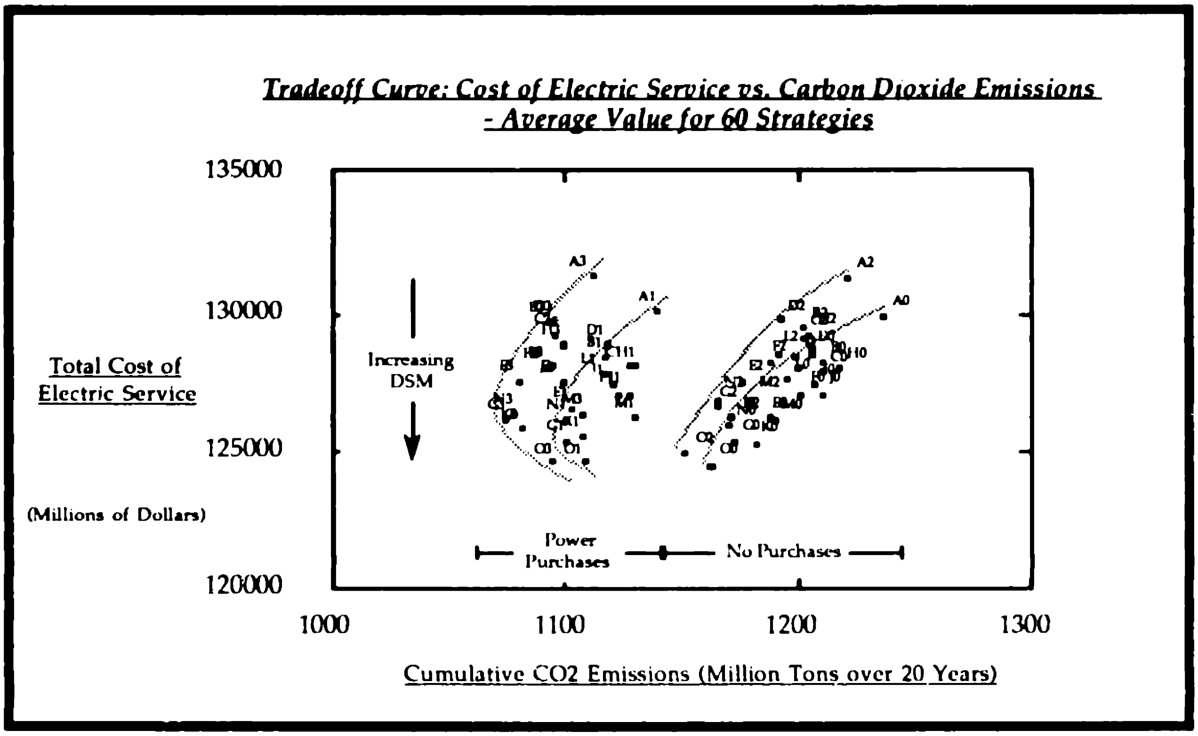
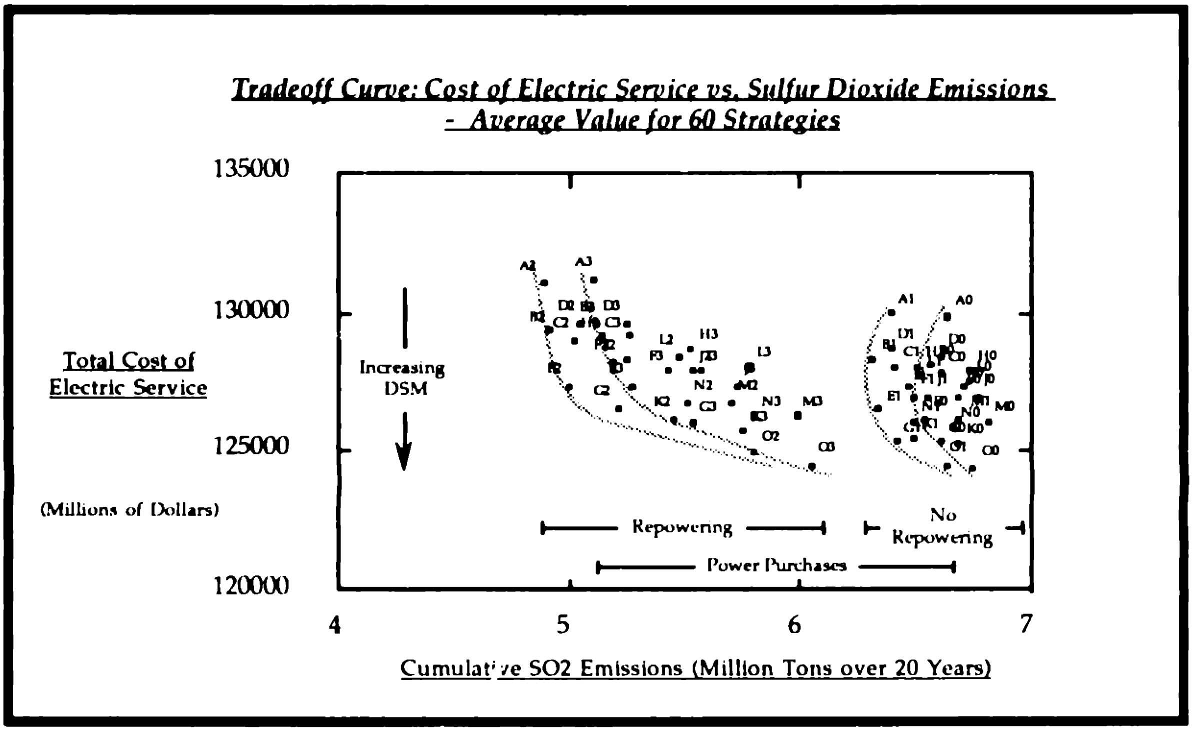


Figure 6-30: Scatter Plot of Cost vs. SO_2 -- Average Values
Source: Connors and Andrews, 1990



The reliability attribute is not shown here because all strategies had roughly the same performance on average. This is not surprising because none of the strategies were targeted towards reliability issues. Since the behavior of the options is consistent regarding the reliability and cost attributes – more DSM reduces costs and the supply options have little effect one way or another – we can focus instead on the interesting interactive effects seen in environment vs. environment tradeoffs.

Figure 6-32 has a regional environmental attribute – cumulative SO_2 emissions – on the vertical axis and a global environmental attribute – cumulative CO_2 emissions – on the horizontal axis. Here the strategies separate into four distinct clusters based on supply option sets. The political status quo – gas dependent (0) – is dominated by all of the other supply option sets on average. Gas plus power purchases (1) is also dominated. The best of the repowering strategies (A2, B2, E2) perform slightly better on SO_2 reductions, but much worse on CO_2 reductions than the best of the strategies with both repowering and power purchases (B3, E3, G3). Therefore the strategies of greatest interest all include repowering, and many of them include power purchases. Somewhat surprisingly, they also include fairly low levels of demand-side investment.

Figure 6-33, with CO2 emissions on the vertical axis and megawatts of new capacity on New England sites on the horizontal axis, shows global versus local environmental tradeoffs. As was the case in the previous plot, there is strong clustering by supply option set. Repowering and power purchases (3) again dominates, even more decisively than before. However, this time the high-DSM strategies (N3, O3) move to the frontier.

Figure 6-31: Scatter Plot of Cost vs. New Site Needs -- Average Values
Source: Connors and Andrews, 1990

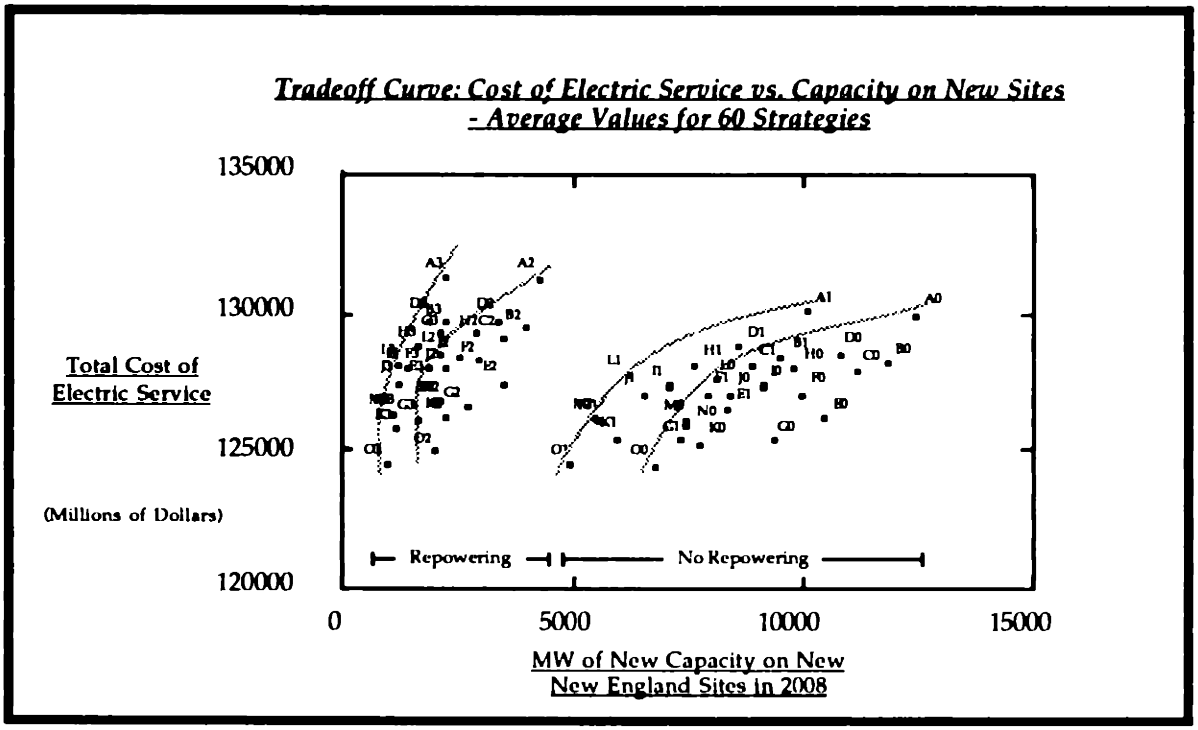


Figure 6-32: Scatter Plot of SO2 vs. CO2 -- Average Values
Source: Connors and Andrews, 1990

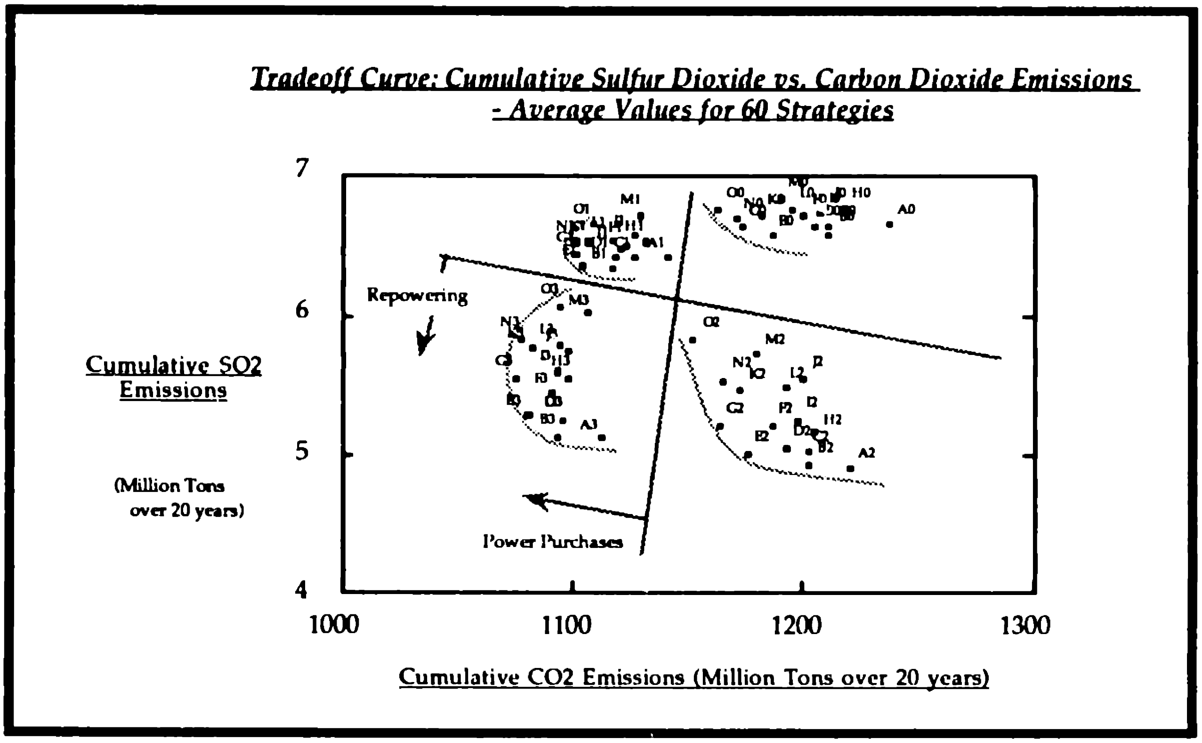
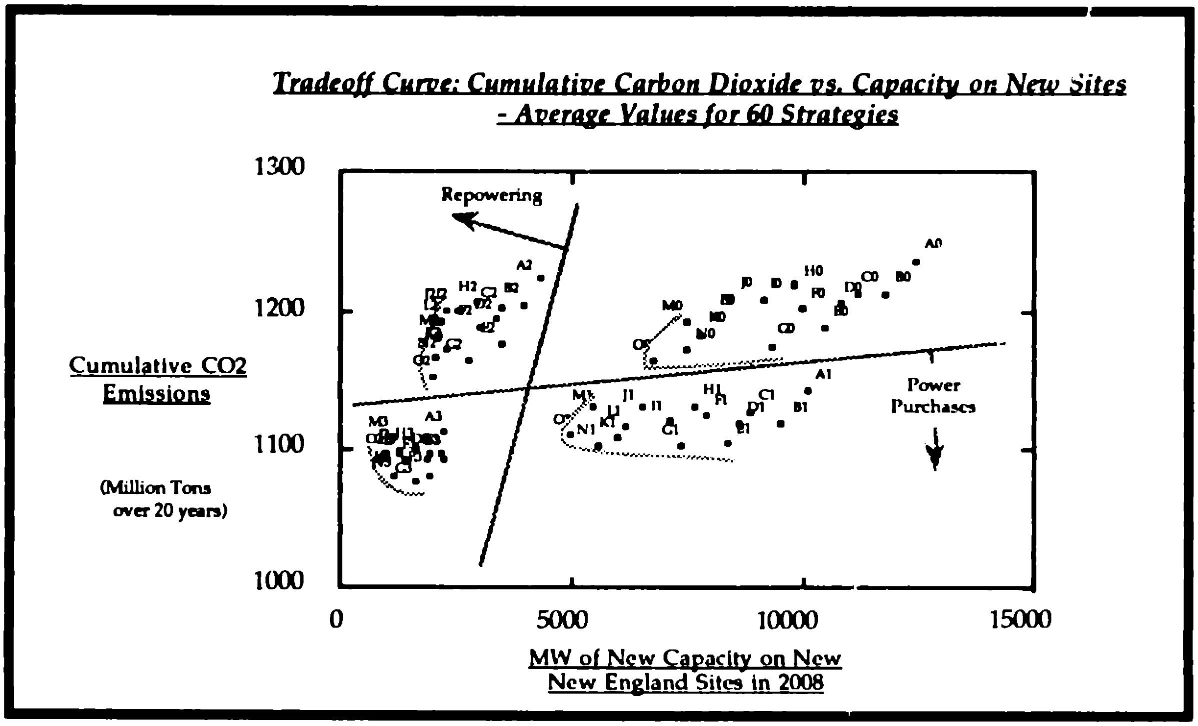


Figure 6-33: Scatter Plot of CO2 vs. New Site Needs -- Average Values
Source: Connors and Andrews, 1990



Several trends may be identified from this tradeoff analysis. If cost is the primary issue, then demand-side management should be of great interest, and repowering and power purchases will not make much of a difference one way or another. If the global environment (CO$_2$) is the focus, then power purchases (because of their large non-fossil component) become the most attractive option, with demand-side management also offering emissions reductions, and repowering not making a significant impact. If the main issue is the regional environment, measured by SO$_2$ emissions, then repowering is the key to a successful strategy, with power purchases helping on their own, but hurting when used in combination with repowering. Demand-side management works against all of the supply option sets modeled, reducing their effectiveness at achieving emissions reductions.

Finally, if local site-related issues are the most important, then DSM, repowering, and power purchases all help to reduce new megawatts on new New England sites. Reliability results appeared to depend more on the modeling approach used than on real planning considerations; therefore they were not considered in this phase of the analysis. None of the options had been targeted towards reliability concerns in this scenario set, so the focus narrowed to cost and environmental issues. Table 6-7 summarizes these trends.

Table 6-7: Trends Identified by the Tradeoff Analysis – Using Median Data
Source: Connors and Andrews 1990

Issue	*Attribute*	*Demand-Side Management*	*Unit Repowering*	*Power Purchases*
Cost	Total Cost	✙	≈	≈
Global Environment	CO2	+	≈	✙
Regional Environment	SO2	−	✙	±
Local Environment	New Sites	+	✙	+

One message to carry away from this part of the analysis is that, in general, the best strategies were multi-faceted, made up of some combination of repowering, power purchases, and demand-side management. Extreme strategies emphasizing a single option were effective at addressing one issue, but often did not perform as well on other issues.

Counter-intuitive results, presumably due to interactions in the complex electric power system, also came into sharper focus. Specifically, repowering was so good at reducing SO2 emissions that the addition of power purchases and demand-side management to the strategy actually made emissions worse instead of better, even though the unit emissions of each of these two options was less than that of repowering, on a kilowatthour-for-kilowatthour basis. Understanding this paradox becomes a crucial step in inventing new strategies with the potential for consensus.

Before pursuing the relationship of repowering, demand-side management and SO_2 emissions, we need to explore the consistency of these results.

3.c.ii. How consistent is the performance of each strategy across various possible futures?

Examine bivariate scatter plots for each future, checking the stability of the strategies' relative positions. Focus especially on the best and worst futures for each attribute pair – if trends are consistent there, then they are likely to remain so for all futures in between.

The univariate consistency checks shown earlier, using Friedman's test statistic and similar measures, confirmed a moderate amount of stability in the strategy rankings for all attributes of interest (except reliability where the range of variability was no longer a focus). Trends identified using median multi-attribute data may therefore be expected to be fairly stable across different futures. However, since small differences in attribute values determine whether a strategy is dominant or dominated, it is important to inspect scatter plots for each future to verify consistency.

With 36 different futures, this step of the analysis is quite time consuming. However, it reveals a tremendous amount about the system that black box summary measures do not. A simple count of the number of times a strategy appears on the tradeoff frontier does not help us understand why that strategy dominates, for example. Wading through futures is a task that the analysis team does not need to share with the advisory group; once the "stories" are found, then they can usually be told quite succinctly with bracketing data – scatterplots for the best and worst futures.

One cannot always guess which will be the best and worst futures for each attribute, because in a complex system many different factors interact to push attribute values up and down. Sorting the scenarios in ascending order for each attribute in turn is the most reliable way to find these best and worst futures. For each attribute pair there can be up to two best and two worst futures (one for each attribute). For example, in the New England data set the worst future for both cost and SO_2 emissions is the same, but the best future for each differs. The best and worst futures for CO_2 emissions matched those for cost. Table 6-8 below identifies these futures.

Table 6-8: Best and Worst Futures

Attribute:	Cost	SO2	CO2
Best Future	LDFB (106 $B)	HDFB (4.43 MMTons)	LDFB (965 MMTons)
Worst Future	H5GE (153 $B)	H5GE (7.53 MMTons)	H5GE (1424 MMTons)

The common worst future has high load growth, interactions among demand-side programs, high gas prices, and expensive demand-side unit costs (H5GE). This makes intuitive sense; it sounds like the worst of all possible combinations of the uncertainty values modeled.

The best future regarding cost has low load growth, no interactions among demand-side programs, normal fuel prices, and below-budget demand-side unit costs (LDFB). This also makes intuitive sense; it sounds like the best of all possible combinations of the uncertainty values modeled. Why then is the best future regarding SO_2 different? Why is it future HDFB, a high load growth future? This counter-intuitive result suggests that SO_2 emissions do not relate closely to the amount of electricity generated, but rather to how it is produced. The generating mix that results from high load growth not only produces less SO_2 per unit of electric energy sold, but also less in aggregate than in lower load growth cases. This unexpected result provides further understanding of the way the complex electric power system works, and helps us to invent yet better strategies.

Figure 6-34 shows cost vs. SO_2 emissions for the worst future (H5GE). The four supply option sets (0, 1, 2, 3) are clustered similar to the way they were using median values for the attributes (see Figure 6-30). Likewise, the lower DSM option sets (A,...G) behave much as they did in the medians plot. However, some of the highest DSM option sets shift to different relative positions in the worst future. Option set O, which was always on the frontier in the medians plot, now moves off it some cases. The least cost-effective DSM option sets on an investment-per-kilowatthour-saved basis (D and L) become more expensive than doing no DSM at all (A) in this worst future.

Figure 6-34: Cost vs. SO2 in New England – for Worst Future

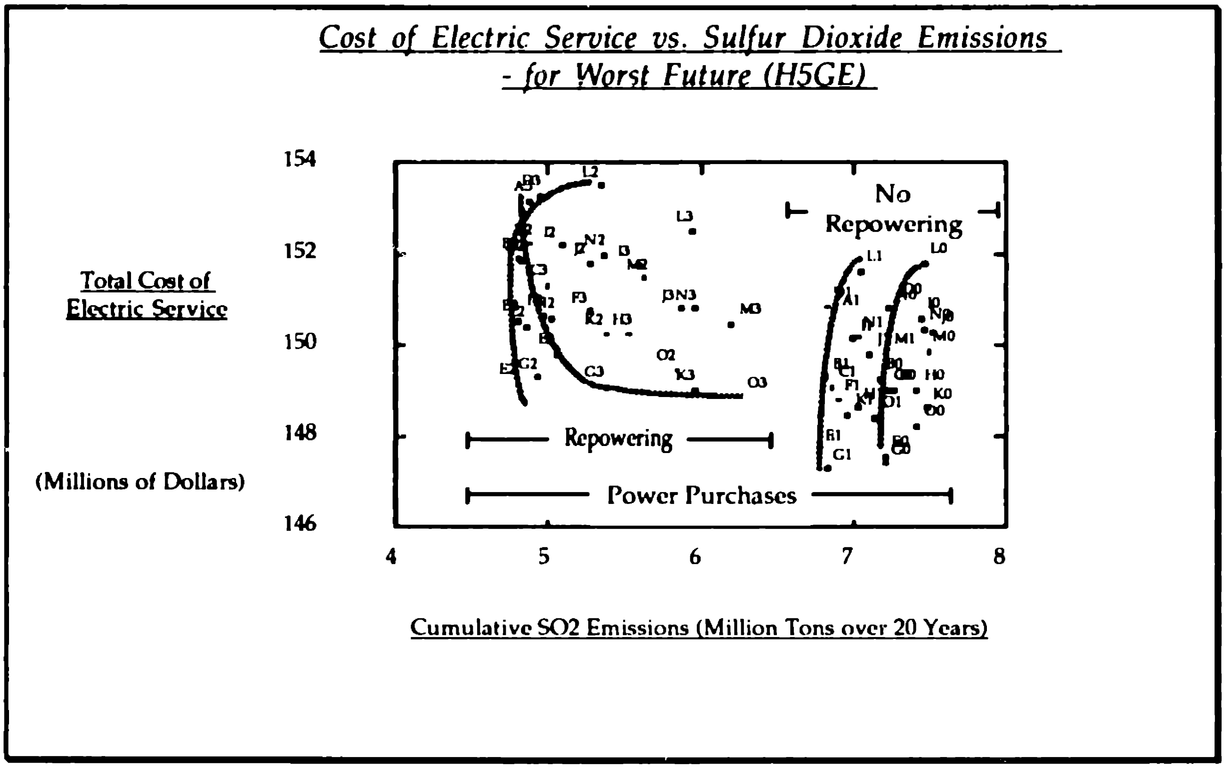


Figure 6-35: Cost vs. SO2 in New England – for Best Future (re. Cost)

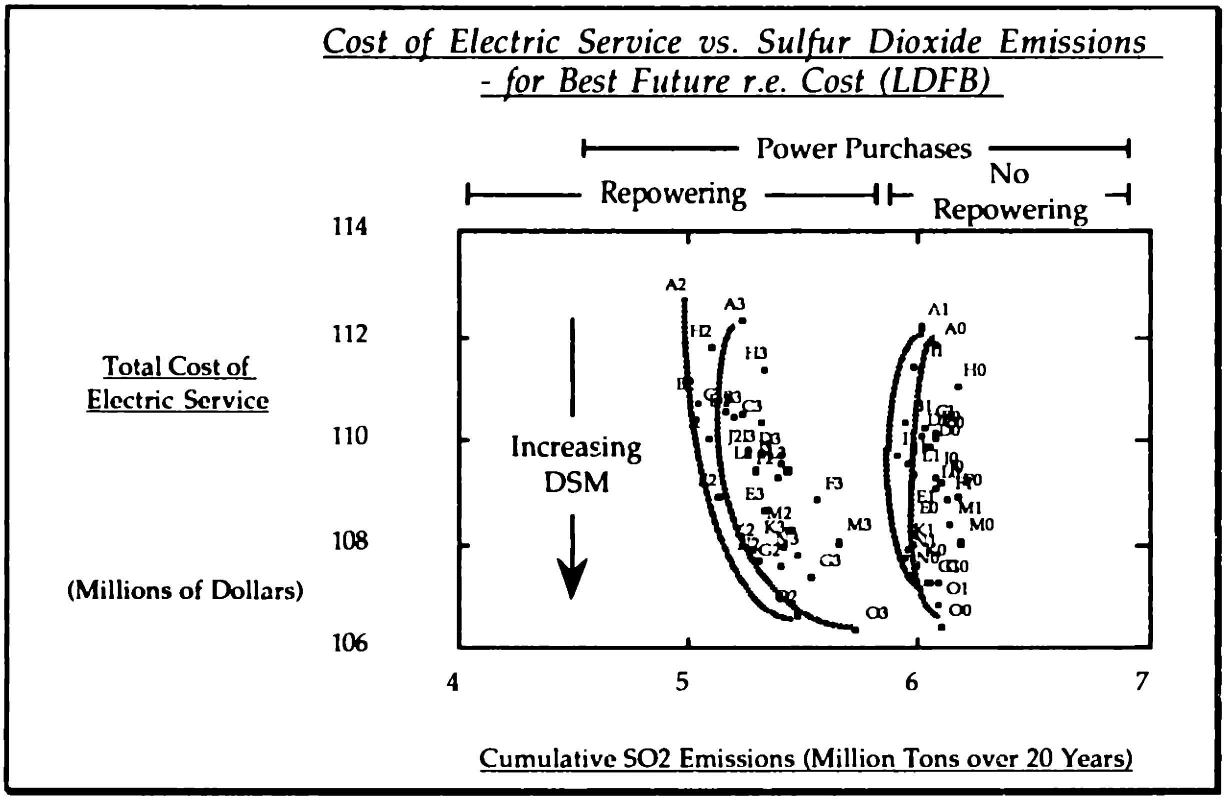
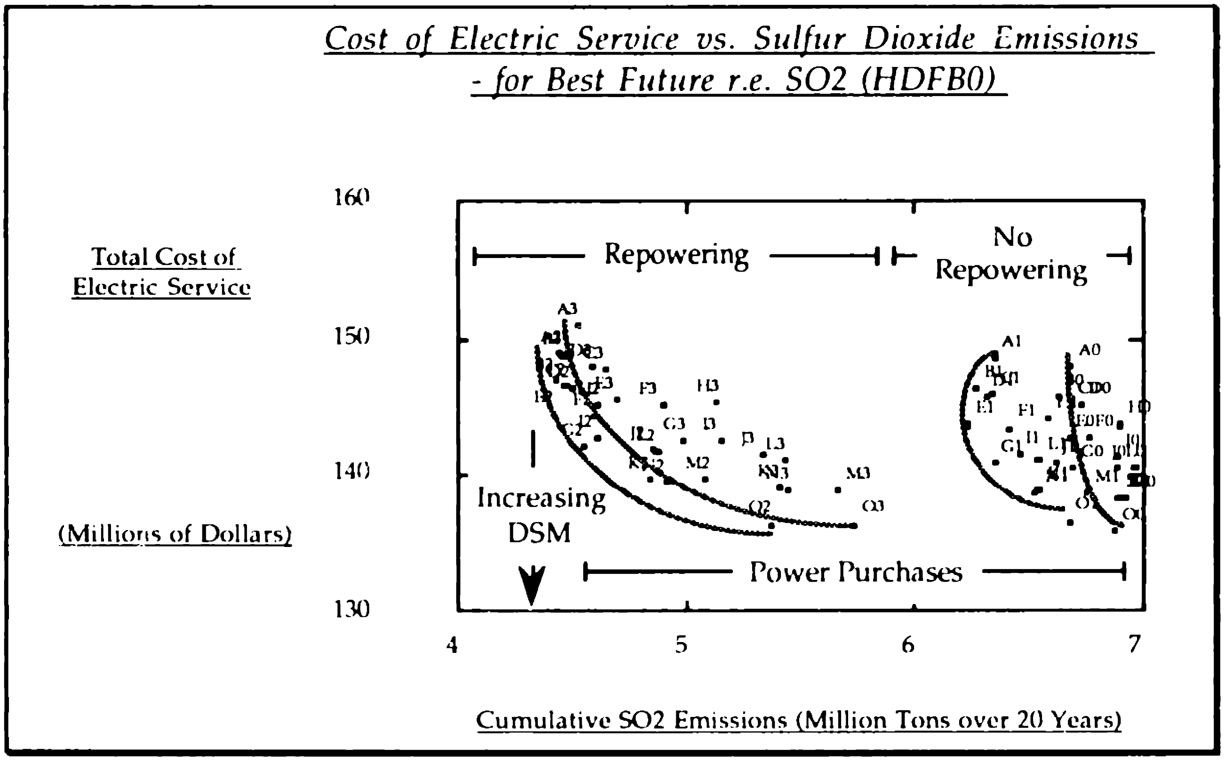


Figure 6-36: Cost vs. SO_2 in New England - for Best Future (re. SO_2)



Figures 6-35 and 6-36 show the best futures for each of cost and SO_2 emissions. Both of these map the strategies into positions nearly identical, on a relative basis, to what we saw using median values. While the absolute impacts of the strategies are quite different in each future, their relative positions are consistent.

3.c.iii. How does each strategy perform considering all attributes?

Summarize the trends identified by the tradeoff analysis considering the effects of uncertainty on the performance of strategies.

By tempering our understanding of the trends identified using median data with future-specific information, we can develop a stronger characterization of the qualities of the options that make up the strategies. Table 6-9 shows the revised summary of the trends identified by the tradeoff analysis across all 36 futures modeled.

Table 6-9: Trends Identified by the Tradeoff Analysis
– Considering the Range of 36 Futures

Issue	***Attribute***	***Demand-Side Management***	***Unit Repowering***	***Power Purchases***
Cost	Total Cost	+	≈	≈
Global Environment	CO2	+	≈	✙
Regional Environment	SO2	—	✙	±
Local Environment	New Sites	+	✙	+

The primary difference between this and Table 6-7 (using median data) is that the DSM component has revealed some instability in extreme cases. Specifically, when less cost-effective option sets such as D and L encounter adverse conditions such as DSM program interactions and expensive unit energy savings costs, then they increase rather than decrease cost, CO_2, and new site requirements (relative to no DSM). Thus the DSM option is not entirely forgiving; it must be done cost-effectively to be valuable. The other components – repowering and power purchases – perform relatively consistently across the range of futures modeled. Note of course that two of the uncertainties modeled (interactions and costs) were targeted specifically at DSM programs, while fuel cost was the only uncertainty targeted at the supply-side options.

Step 3.d. Observe the performance of the system

In addition to slicing up the data by option, option set, uncertainty value, and future, it is also worthwhile to look at patterns in the data set as a whole. Two ways to do this are with correlations and regression analysis.

3.d.i. *Do different attributes correlate with one another?*

Create a correlation matrix using Pearson's r, and look for highly correlated attributes. Seek to explain each significant correlation; look for clues that help to explain previous counter-intuitive results.

The correlation matrix for 41 attributes measured across 2160 scenarios serves several purposes. First, it provides a sanity check on the modeling, by confirming that expected relationships between attributes in fact exist, so that, for example, energy production is highly correlated with energy sales. Second, it indicates when one attribute may be reasonably used as a proxy for several similar attributes. For example, the extremely high correlation between total suspended particulates (TSP) and SO_2 emissions lets us focus on SO2 alone for much of the analytic work. Similarly, the extremely high correlation between hours in O.P.4 Levels 3 through 15 (plus O.P. 7 or blackout) lets us use one of them, O.P. 4 Level 13 (voltage reductions) as our single reliability attribute. The third purpose of the correlation matrix is to help us understand our counter-intuitive results, thereby improving our understanding of the complex system, and enhancing our ability to develop better strategies for its planning and operation.

The attribute that behaves in the most surprising way in this data set is cumulative SO_2 emissions. Unlike CO_2 emissions, it seems unrelated to the amount of electricity generated. Indeed, cumulative SO_2 totals appear to be higher after 20 years of high-DSM investment strategies than if investments had only taken place on the supply side. Repowering of plants greater than 30 years of age and larger than 40 megawatts in size appears to be the single most effective way to reduce SO_2 emissions that was modeled in this scenario set. The obvious question becomes: what does SO_2 emissions correlate with?

Table 6-10: Pearson's r Correlation Matrix for New England

Attributes	*Electricity Sales*	*Oil 6 Consumption*
SO2	0.017	0.968
NOx	0.640	0.810
TSP	0.310	0.978
CO2	0.908	0.284
Total Cost	0.988	0.167

As Table 6-10 shows, both cost and CO_2 emissions are highly correlated with electricity sales, while SO_2 (and TSP) emissions correlate quite poorly with sales. However, SO_2 (and TSP) emissions show an extremely strong correlation with Oil #6 consumption.

New England's oil-fired power plants appear to be the region's primary sources of SO_2 (and TSP) emissions. A look at the data characterizing the region's fossil-fired power plants makes things clearer. As Table 6-11 shows, more than half of New England's fossil-fired capacity (and about one third of total generating capacity) burns No. 6 fuel oil. The average operating efficiency of these plants (32.1%) is quite low compared to new technology. For example, new gas turbine combined cycle plants operate in excess of 40% efficiency; even new coal plants achieve 38% efficiency (AGREA 1990). The sulfur and particulates content of both natural gas and distillate oil (oil #2) are much less than that of oil #6; thus a shift towards those fuels also can reduce emissions.

Table 6-11: New England's Fossil-Fired Generating Capacity
Source: Based on Andrews et al 1990

	Number of Units	Rated Capacity (MW)	Forced Outage Rate	Average Heat Rate (Btu/kWh)	Average Efficiency (%)
Coal-Fired	15	3151	0.086	10025	34.2
Oil 2-Fired	96	2079	0.109	11825	29.8
Gas-Fired	8	165	0.095	10491	32.6
Oil 6 Fired Generating Capacity					
Time Period	Number of Units	Rated Capacity	F.O.R.	Average Heat Rate	Average Efficiency
Prior 1951	16	602	0.059	12922	27.6
1951 - 1955	10	420	0.053	12445	28.0
1956 - 1960	11	1120	0.068	10372	33.0
1961 - 1965	6	1211	0.082	9720	35.0
1966 - 1970	3	930	0.084	10533	33.4
1971 - 1975	7	2915	0.080	10351	32.9
1976 - 1980	2	1162	0.082	9748	34.9
1981 - 1985	-	-	-	-	-
1986 - 1990	-	-	-	-	-
All Years	55	8360	0.073	10870	32.1
Total Fossil-Fired Generating Capacity					
All Units	174	13755	0.093	10956	32.5
Total Generating Capacity from All Sources					
		24294			

3.d.ii. Do some attributes explain others?

Attempt to develop a multivariate least squares linear regression model that predicts the behavior of one attribute in terms of others. Test hypotheses about system behavior with different regression formulations.

The data set of multiple attribute vectors for 2160 scenarios provides a series of snapshots of the way New England's electric power system behaves. Regression analysis allows us to test hypotheses about the factors that influence the performance of different strategies. Such analysis of several static sets of results can provide useful guidance, not for extrapolation towards behavior under conditions not yet modeled, but to illuminate the linkages among variables.

On the New England project, regression analysis allows us to test hypotheses regarding the counter-intuitive SO_2 emissions results described above. One model formulation is shown below.

The model (see Table 6-12) attempts to predict SO_2 emissions based on fuel consumption and electricity sales. As earlier analysis has shown, oil#6 consumption has a strong explanatory effect regarding SO_2 emissions. Coal consumption also appears to be important. Oil#2 consumption does not appear to be a significant factor, while natural gas consumption does appear to be significant, but in a negative direction. This suggests that natural gas, a clean fuel, can reduce SO_2 emissions by substituting for dirty oil#6 and coal. Oil#2 also has a low sulfur content relative to oil#6 and coal, but it enjoys only minimal use because it has a high unit cost. The magnitude of electricity sales also has some explanatory power, albeit less than the fuel mix which provides the electricity. This analysis provides deeper insights than the simple correlation matrix (Table 6-10) by showing that, as one would intuitively expect, the magnitude of electricity sales does have some relationship to SO_2 emissions. However, it is less important than some other factors in producing those emissions.

Table 6-12: Regression Model

MODEL: Predict SO_2 Emissions Based on Fuel Consumption and Electricity Sales

```
MODEL CONTAINS NO CONSTANT.

DEPENDENT VARIABLE:    SO2 (LBS)     N: 2160          MULTIPLE R: 1.000
SQUARED MULTIPLE R: 1.000
ADJUSTED SQUARED MULTIPLE R: 1.000
STANDARD ERROR OF ESTIMATE:  .158354E+09

VARIABLE            COEFFICIENT        STD ERROR   STD COEF     T

OIL6 (MMBTU)        4.661              0.022       0.388        212.712
GAS (MMBTU)         -0.119             0.005       -0.021       -25.589
OIL2 (MMBTU)        0.000              0.049       0.000        0.004
COAL  (MMBTU)       42.824             0.343       0.393        124.961
GWHSALES (GWH)      1173.676           22.744      0.243        51.604

ANALYSIS OF VARIANCE

SOURCE        SUM-OF-SQUARES    DF      MEAN-SQUARE

REGRESSION  .314992E+24         5       .629983E+23
RESIDUAL     .540388E+20        2155    .250760E+17
```

Note that a very good fit ($R^2 = 1.000$) was achieved in this model. That was feasible because the model was based on simulation results, not real life. Models such as these helped the analysis team verify their "stories," but they were too arcane to present to an advisory group as evidence. In the November meeting of the New England advisory group, such models were presented, but failed to convey the message as well as graphics did.

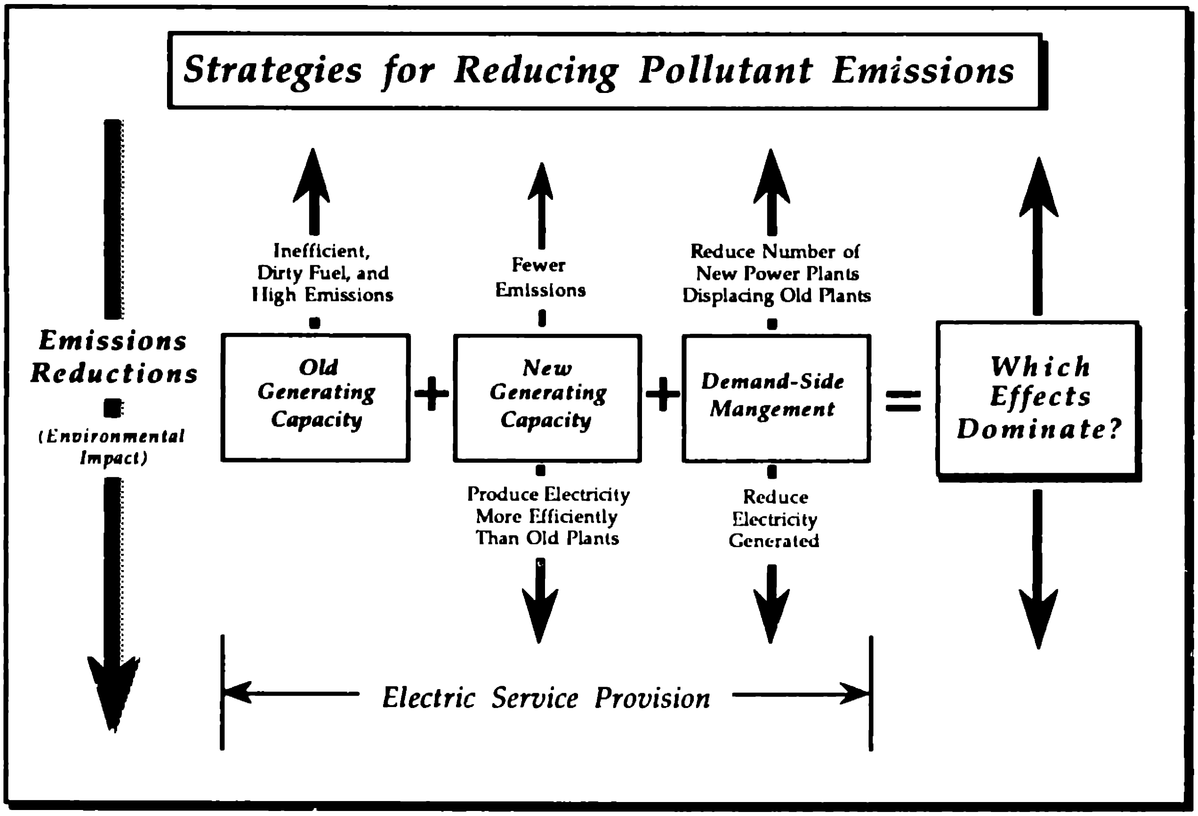
Step 3.e. Invent better strategies and explore more relevant uncertainties

The purpose of exploring the behavior of the complex electric power system in the intense detail shown in this chapter is to spur the inventiveness of the advisory group (and analysis team) in developing strategies with the potential for consensus. In order to do so, the characteristics of the options that make up strategies, their interactive effects, and their vulnerability to uncertain future events all must be understood by the advisory group. It is the job of the analysis team to synthesize this information and present it in a comprehensible form that encourages creative thinking by members of the advisory group.

> ***3.e.i.*** ***Based on what we have learned about the system's behavior, which additional strategies need to be evaluated?***
>
> ***Use the characteristics of preferred strategies from the current scenario set to encourage brainstorming for additional strategies more likely to meet with consensus.***

The sulfur dioxide emissions paradox highlighted in this scenario set, for example, needed to be explained to the advisory group in order to get several important system characteristics out on the table. This was achieved graphically using Figure 6-37 to succinctly synthesize the previous evidence. This picture makes the points that: (1) electric service is provided by a combination of new generating capacity, demand-side management activities, and existing capacity, (2) new generating capacity is more efficient and cleaner than old capacity, (3) demand-side management reduces the amount of electricity that must be generated, (4) demand-side management unfortunately also obviates the need for new clean capacity, and (5) the overall effect on emissions is hard to predict *a priori*.

Figure 6-37: Strategies for Reducing Pollutant Emissions
Source: Andrews et al 1990



The policy debate until this point had focused mainly on choices between new capacity and demand-side management; the role of existing capacity in pollution reduction strategies had largely been ignored. This scenario set suggested that, for SO_2 emissions at least, investments in DSM were, watt-for-watt, a less effective pollution reduction strategy than investments in new supply. This is because DSM only reduced generic, system average kilowatthours, and with a fairly low annual capacity factor. However, new supply, being cheaper to operate than existing capacity, caused the old, dirty plants to run much less often, thus reducing the specific kilowatthours causing the SO_2 pollution. This was especially true for the repowering supply option, which targeted the worst of the existing capacity, ensuring that it went off line.

The power purchases supply option set had the special characteristic of being, in part, a non-fossil (hydro and nuclear) generating source. The success of this option set in reducing emissions pointed out to the advisory group the role that non-fossil generation could play in designing pollution reduction strategies. Similarly, the emissions reduction effect of substituting natural gas for oil#6 spurred the group to suggest other types of fuel substitutions.

All of these different emissions reduction options begged for a framework within which to be placed. After the February 1990 advisory group meeting, while making a series of presentations to interested parties regionwide, I developed the following identity to help people think about the wide array of options that could be packaged into an SO_2 emissions reduction strategy. The following factors affect SO_2 emissions:

$$\begin{matrix} SO_2 \\ \text{Emissions} \\ \text{(lbs)} \end{matrix} = \begin{matrix} \text{Total} \\ \text{kWh} \\ \text{Produced} \end{matrix} \times \frac{\text{Fossil kWh Produced}}{\text{Total kWh Produced}} \times \frac{\text{Btu Fuel Input}}{\text{Fossil kWh Produced}} \times \frac{\text{Sulfur (lbs) Content}}{\text{Btu Fuel Input}} \times \frac{\text{Sulfur (lbs) Emitted}}{\text{Sulfur (lbs) Content}}$$

Each term in this identity suggests a component of an emissions reduction strategy, as follows:

End-Use Efficiency	Non-Fossil Generation	Combustion Efficiency	Fuel Choice	Emissions Controls

Specific options within this framework include:

Utility DSM Standards	Photovoltaics Nuclear	Combined-Cycle	Natural Gas Low Sulfur Oil	Scrubbers Catalytic Redux

Combining these types of options into strategies provides the basis for the next round of scenario analysis.

3.e.ii. Are there other uncertainties to consider?

Anticipate the potential weaknesses of the new strategies, and select uncertainties that test the changes in their performance under adverse conditions.

The current data set tested demand-side management and gas-dependent strategies under adverse conditions, by providing uncertainties focused on them: DSM program interactions, DSM unit cost variation, and gas price variation. The next data set should test additional uncertainties. For example, since photovoltaics and nuclear technologies are extremely capital-intensive, then variation in capital costs would be important to consider. Likewise, if utilities all over the region switched to low sulfur oil #6, this could affect its price, so fuel oil price variation should be considered.

Efficacy of Step 3 in the New England Project

The third step of the scenario-based multi-attribute tradeoff analysis framework was an intellectual exploration of the behavior of New England's complex electric power system. The dual purposes for this were to (1) develop a shared understanding of the current situation, the options available, and their likely impacts, among the various stakeholders, and (2) spur them to invent better strategies than were previously on the table.

The large data set that was generated by the analysis team needed to be interpreted for and by the participants in the open planning effort. The graphical and statistical tools demonstrated in this chapter showed varying degrees of usefulness when applied to this task. Some were useful to both the analysis team and the advisory group, while others were found to be helpful only by the analysis team. Some of the tools were not even very useful to the analysts. Based on discussions with the analysts, advisory group, and others who attended presentations of the work, the usefulness of each of the tools in practice is summarized in Table 6-13.

The more arcane statistical tests were, not surprisingly, less useful for communicating the results to an audience than were graphical techniques, although both were often valuable to the analysis team in sifting through the data.

While the scenario-based multi-attribute tradeoff analysis technique reduced the normative content of the modeling by exploring a range of uncertainties and using many attributes, a new opportunity for bias presented itself during its application to the New England project. This was the fact that, with so much information contained in the final data set (2160 scenarios x 41 attributes), only the analysis team had the time to thoroughly explore the results. The advisory group depended on the analysts to interpret the results for them, and to point out the most important conclusions. Of the many conclusions that could be discussed, the analysts had to select those that were most relevant to the policy issues at hand. This was obviously an extremely subjective task.

Table 6-13: Efficacy of Methods for Exploring System Behavior (Initial Framework) as Applied on the New England Project

		Useful to Analysis Team?	***Useful to Advisory Group and Public?***
3.a.	**Observe the effects of uncertainty.**		
i.	*Over what ranges do impacts vary?*	Yes	Yes
ii.	*How relevant are the different uncertainties?*	Yes	Yes
iii.	*How different are the various futures?*	Yes	Yes
3.b.	**Observe the performance of strategies – one attribute at a time.**		
i.	*How do individual options perform along various attributes?*	Yes	No
ii.	*How does each option set perform along various attributes?*	Yes	Yes
iii.	*How consistent is the performance of each option set across various possible futures?*	Yes	No
iv.	*How does each strategy perform along various attributes?*	Yes	No
v.	*How do the strategies rank relative to one another along attribute A? B? C?*	Yes	No
vi.	*How consistent are strategy rankings across different futures?*	Yes	No
vii.	*How consistent is the performance of each strategy across various possible futures?*	Yes	No
viii.	*Do different uncertainties affect different strategies?*	Yes	No
3.c.	**Observe the performance of strategies – consider multiple attributes.**		
i.	*How does each strategy perform for different attribute pairings?*	Yes	Yes
ii.	*How consistent is the performance of each strategy across various possible futures?*	Yes	Yes
iii.	*How does each strategy perform considering all attributes?*	Yes	Yes
3.d.	**Observe the performance of the system.**		
i.	*Do different attributes correlate with one another?*	Yes	Yes
ii.	*Do some attributes explain others?*	Yes	No
3.e.	**Invent better strategies and explore more relevant uncertainties.**		
i.	*Based on what we have learned about the system's behavior, which additional strategies need to be evaluated?*	Yes	Yes
ii.	*Are there other uncertainties to consider?*	Yes	Yes

The analysis team developed a strategy of mining the data for "stories" that could be convincingly told to the advisory group. A "story" had to: (1) establish that a widely believed phenomenon was indeed true in New England's case, such as total costs decreasing with increased DSM effort, or (2) show that a counter-intuitive result was really plausible, such as SO_2 emissions increasing with increased DSM effort. Adequate evidence, from the data set and elsewhere, had to be demonstrated for a "story" to be acceptable. Rules of formal scientific enquiry governed the selection and compilation of the "stories," but the final choice of which few of them to present in depth was a subjective task undertaken by the analysts.

The process of iterative advisory group/analysis team interactions provided a check against this type of bias, to the extent that participants always had the option of requesting more information about topics not covered, and "stories" not told. However, explicitly acknowledging the potential for this type of bias was probably the best way to minimize its effects.

Understanding the behavior of New England's complex electric power system was one important stage in the process of developing strategies with the potential for consensus; the other, understanding stakeholders' preferences, is discussed in the next chapter.

7. UNDERSTANDING PARTICIPANTS' PREFERENCES IN THE NEW ENGLAND PROJECT

The fourth step in the scenario-based multi-attribute tradeoff analysis framework described in Chapter Four was preference elicitation. For the New England project, its objective was to help the analysts understand the preferences of the participants in the advisory group. An improved understanding of their preferences was assumed to be important in identifying strategies with the potential for consensus. This phase of the project included the series of discrete tasks listed in Table 7-1 and described below.

Table 7-1: Understand Peoples' Preferences (Initial Framework)

4.a. Sort through the strategies – slowly add normative content to the decision rules.
  i. Which strategies are dominated by others across all attributes and futures?
  ii. Which strategies are dominated by others across all attributes , if equal probabilities are assigned are assigned to all futures?
  iii. Assuming risk-aversion, how does the decision set change?
  iv. Emphasizing different futures, how does the decision set change?
  v. Emphasizing different attributes, how does the decision set change?

4.b. Elicit stakeholder values.
  i. How do different parties prioritize attributes?
  ii. How do different parties view uncertainty?
  iii. How do different parties view the various strategies?

4.c. Undertake conflict analysis.
  i. What are the areas of conflict?
  ii. Where is the common ground?

4.d. Invent better strategies.
  i. Are there new packages of options that have more of the characteristics everyone prefers?
  ii. What new strategies have the potential for consensus?

Repeat steps 1 to 4 above if necessary.....

Step 4.a. Sort through the strategies – slowly add normative content to the decision rules.

All analytic work has substantial normative content, that is, it is laced with value judgements and arbitrary assumptions. In a consensus-building process, where different parties start with different assumptions about the way the world behaves, the framework should minimize the controversial aspects of the initial analytic tasks. If consensus is achieved regarding particular assumptions, then they become valid for use in modeling. If no consensus can be reached on the value of a particular variable, then it gets treated as an uncertainty, and a range of values is modeled. The scenario-based multi-attribute tradeoff analysis framework seeks to do this in its initial stages.

The same philosophy applies in the preference elicitation phase. Here, the options are sorted in a variety of ways to reveal their behavior across attributes and uncertainties. Initial sorts are made as "value-free" as possible so that they will have meaning for all stakeholders. Normative content is slowly added to subsequent sorts, first through the use of "generic value-laden sorts," and then with stakeholder-specific sorts. One goal of this approach is to postpone the need for making probability assignments for as long as possible. Since assigning probabilities to different futures is a highly subjective task, once it is done then subsequent analysis is "tainted" by that additional set of value judgements. The initial sorting techniques thus use decision rules that do not require probability assignments. This set of procedures is intended to clarify, for a group with diverse opinions, the tradeoffs resulting from choices among the various strategies that are on the table.

4.a.i. Which strategies are strictly dominated by others across all attributes and futures?

Test for non-probabilistic or absolute dominance of strategies across all attributes.

The tradeoff analysis begins using absolute, or non-probabilistic dominance as the sorting criterion. Under this decision rule, strategy A will be preferred over strategy B along attribute X if its value is always less than that for strategy B, regardless of uncertainty. More formally, for attribute X, strategy A absolutely dominates strategy B if Max X^A < Min X^B where lower values of the attribute are always preferred. This is shown graphically in Figure 7-1, where the entire probability distribution for strategy A lies to the left of that for B. Although illustrative, these graphics were developed using actual numbers and functional forms as part of this research.

Table 7-2 shows the maximum and minimum values (across 36 futures) of SO_2 and cost for each strategy in the February 1990 New England data set, sorted in ascending order. This presentation allows us to quickly check whether there is absolute dominance. Some strategies do absolutely dominate other strategies along the SO_2 axis. For example, the maximum value of SO2 emissions for strategy A2 is less than the minimum values for strategies L3, N3, M3, O3, I1, B1, N1, J1, K1, E1, N0, E0, H1, L1, K0, A1, D1, C1, D0, G1, B0, L0, A0, C0, I0, G0, O1, J0, O0, F1, M1, F0, H0, and M0. By contrast, no strategy absolutely dominates any other along the cost axis – the lowest maximum cost is substantially higher than the highest minimum cost.

Figure 7-1: Absolute Dominance of Strategy A over B

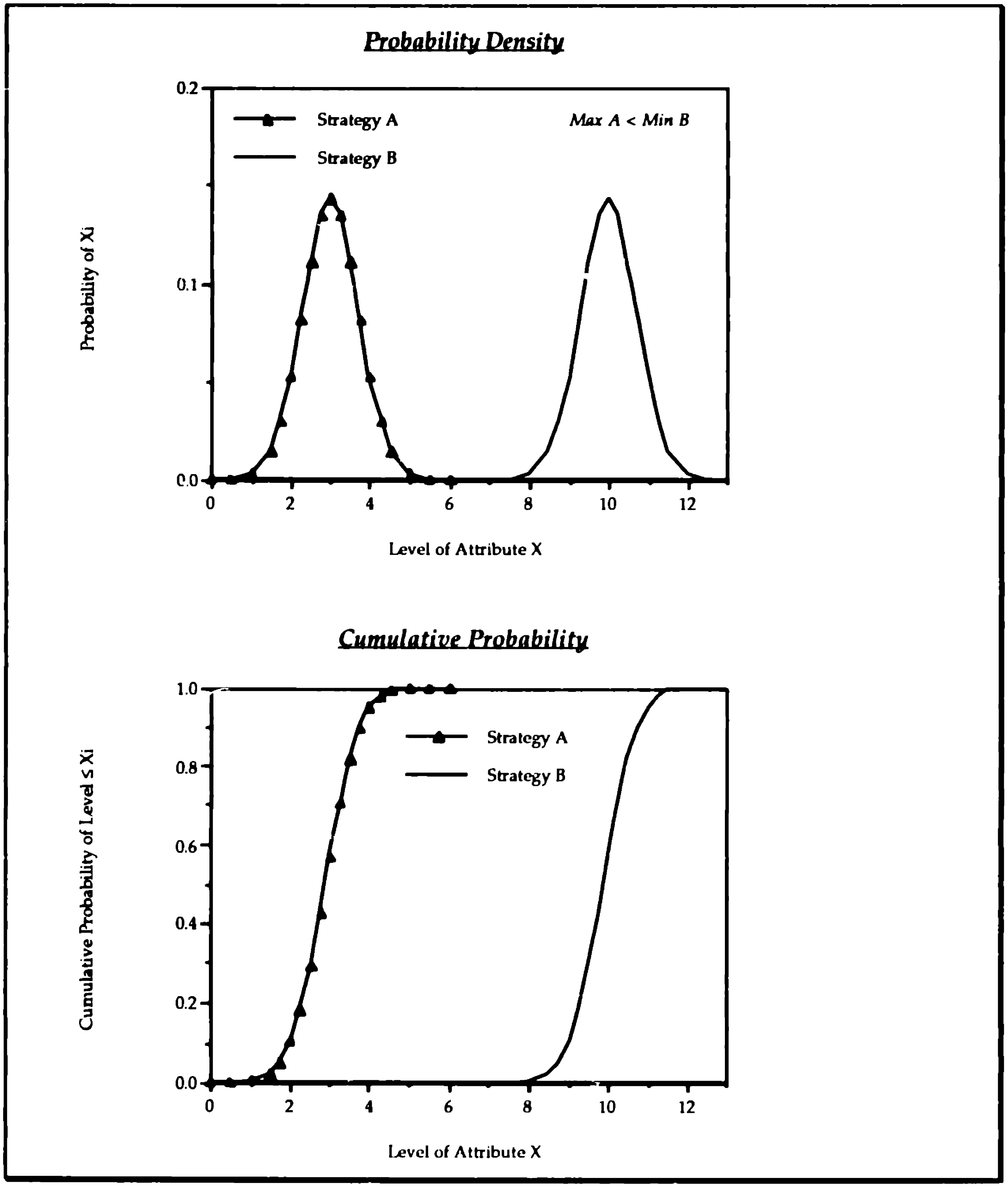


Table 7-2: Identifying Absolutely Dominated Strategies

Identifying Absolutely Dominated Strategies (Max A < Min B)

Attribute: SO2 (Million Tons)

Strategies sorted in ascending order.

Maximum SO2	Strategy	Minimum SO2	Strategy
5.41	A2	4.42	F2
5.48	B2	4.44	B2
5.57	H2	4.46	A2
5.58	E2	4.47	B3
5.61	C2	4.49	C2
5.63	D2	4.50	D2
5.66	A3	4.53	A3
5.66	B3	4.56	E2
5.75	I2	4.59	D3
5.76	C3	4.60	G2
5.76	E3	4.62	H2
5.81	F2	4.62	I2
5.82	G2	4.65	C3
5.84	D3	4.70	F3
5.88	H3	4.85	K2
5.92	J2	4.86	J2
5.96	G3	4.88	L2
5.97	I3	4.90	E3
5.99	F3	4.91	N2
5.99	L2	4.99	G3
6.00	K2	5.09	M2
6.04	N2	5.14	H3
6.12	J3	5.17	I3
6.12	K3	5.24	J3
6.18	N3	5.38	O2
6.19	L3	5.41	K3
6.20	M2	5.44	L3
6.28	O2	5.45	N3
6.36	M3	5.67	M3
6.42	O3	5.74	O3
6.70	E1	5.91	I1
6.82	B1	5.95	B1
6.84	D1	5.95	N1
6.86	G1	5.96	J1
6.87	C1	5.96	K1
6.89	A1	5.97	E1
6.91	I1	5.97	N0
6.97	K1	5.98	E0
7.00	J1	5.99	H1
7.03	H1	5.99	L1
7.03	N1	6.00	K0
7.05	L1	6.02	A1
7.12	F1	6.02	D1
7.15	O1	6.04	C1
7.18	B0	6.05	D0
7.21	E0	6.05	G1
7.21	C0	6.07	B0
7.22	M1	6.07	L0
7.23	G0	6.08	A0
7.24	A0	6.08	C0
7.27	I0	6.08	I0
7.28	D0	6.09	G0
7.42	H0	6.09	O1
7.42	O0	6.10	J0
7.44	F0	6.10	O0
7.46	N0	6.13	F1
7.47	L0	6.14	M1
7.48	K0	6.17	F0
7.49	M0	6.17	H0
7.53	J0	6.19	M0

Attribute: Total Cost of Elect. Svc. (MM$)

Strategies sorted in ascending order.

Maximum Cost	Strategy	Minimum Cost	Strategy
147283	G1	106030	O0
147420	G0	106393	D0
147567	F0	106622	O2
147683	E1	106806	O1
148202	O0	107215	G1
148384	O1	107249	F0
148430	K1	107326	G0
148623	H1	107388	N0
148632	K0	107545	K0
148799	F1	107586	G2
148842	O3	107686	N2
148979	C0	107728	N1
148992	H0	107788	N3
148998	I0	107877	K1
149000	K3	107901	K2
149030	G3	107926	K3
149081	C1	107994	M3
149118	E2	108000	M0
149205	B0	108240	M2
149283	B1	108331	E0
149285	G2	108355	M1
149460	O2	108543	E1
149749	M1	108612	E3
149782	E3	108847	F3
149801	J1	108856	F1
149828	M0	108904	E2
150115	I1	108913	H0
150187	N1	109030	L0
150190	K2	109193	J0
150226	H3	109294	F2
150286	J2	109298	I0
150346	N0	109331	L1
150402	C2	109382	L3
150438	M3	109410	L2
150504	B2	109485	J1
150523	J0	109515	J3
150549	H2	109654	I1
150603	F2	109688	O3
150665	A1	109694	J2
150736	F3	109713	I3
150771	I2	109813	D0
150785	A0	109976	I2
150787	N3	110002	C0
150842	D1	110060	D1
150858	D0	110088	B0
151276	C3	110239	C1
151482	M2	110327	B1
151575	L1	110343	C3
151702	J3	110413	D2
151767	L0	110484	B3
151785	I2	110549	C2
151840	A2	110727	B2
151848	B3	110989	H0
151906	N2	111327	H3
152128	J2	111389	H1
152177	D2	111773	H2
152481	L3	111795	A0
153138	A3	112125	A1
153237	D3	112272	A3
153474	L2	112612	A2

Based on this quick inspection, we can say that no strategy absolutely dominates across all futures and attributes. However, for specific attributes, such as SO_2, some strategies clearly dominate others across all futures modeled. As was noted in the previous chapter, the gas-dependent supply option sets (0, 1) are clearly dominated by those with repowering (2, 3), and especially by low-DSM strategies (A2, B2).

4.a.ii. Which strategies are dominated by others across all attributes, if equal probabilities are assigned to all futures?

Test for first stochastic dominance (FSD) giving all attributes equal weights and all futures equal probabilities.

This step used what finance theorists call First Stochastic Dominance (FSD) as the sorting criterion. Formally, under this decision rule, strategy A is preferred over strategy B along attribute X (independently of the concavity or convexity of the decision maker's utility function, but where smaller amounts of X are desired[1]) if across the entire cumulative probability distributions A and B, $A(X) \geq B(X)$ for all values of X, and where they are not identical distributions. When applied across multiple attributes X, Y, Z, etc., this sorting rule eliminates only those options that are dominated under all futures modeled and across all attributes (derived from Levy & Sarnat, 1984). This is a generalization of the deterministic "significant dominance" criterion proposed by Schweppe and Merrill (EPRI, 1988) (see Figure 7-2).

The FSD sort was implemented using cumulative probability distributions developed from the scenario data base. Initially, equal probabilities were assigned to all futures studied, and equal weights assigned

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[1] Unlike the applications of these concepts in finance theory, where more of an attribute (such as rate of return) is typically preferred to less, in the electricity planning context we prefer to achieve lower levels of the attributes measured (such as cost and emissions).

to all attributes. In later steps, more normative sorts adjusted the probabilities assigned to the various futures. Figures 7-3 and 7-4 show such distributions for selected strategies, for the attribute of SO_2 emissions.

Figure 7-2: First Stochastic Dominance of Strategy A over B

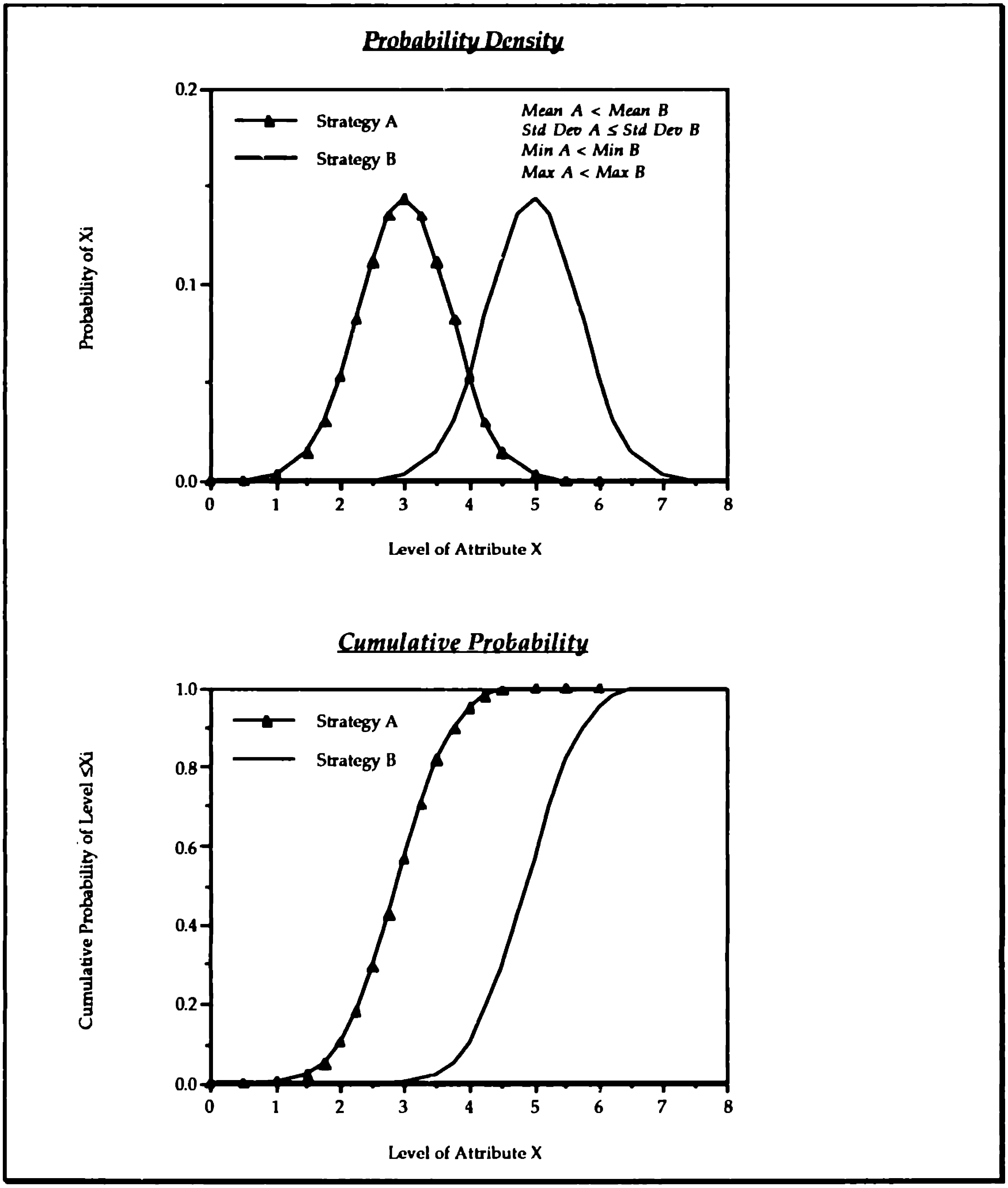


Figure 7-3: Cumulative Probability Distributions of SO_2 Emissions by Strategy

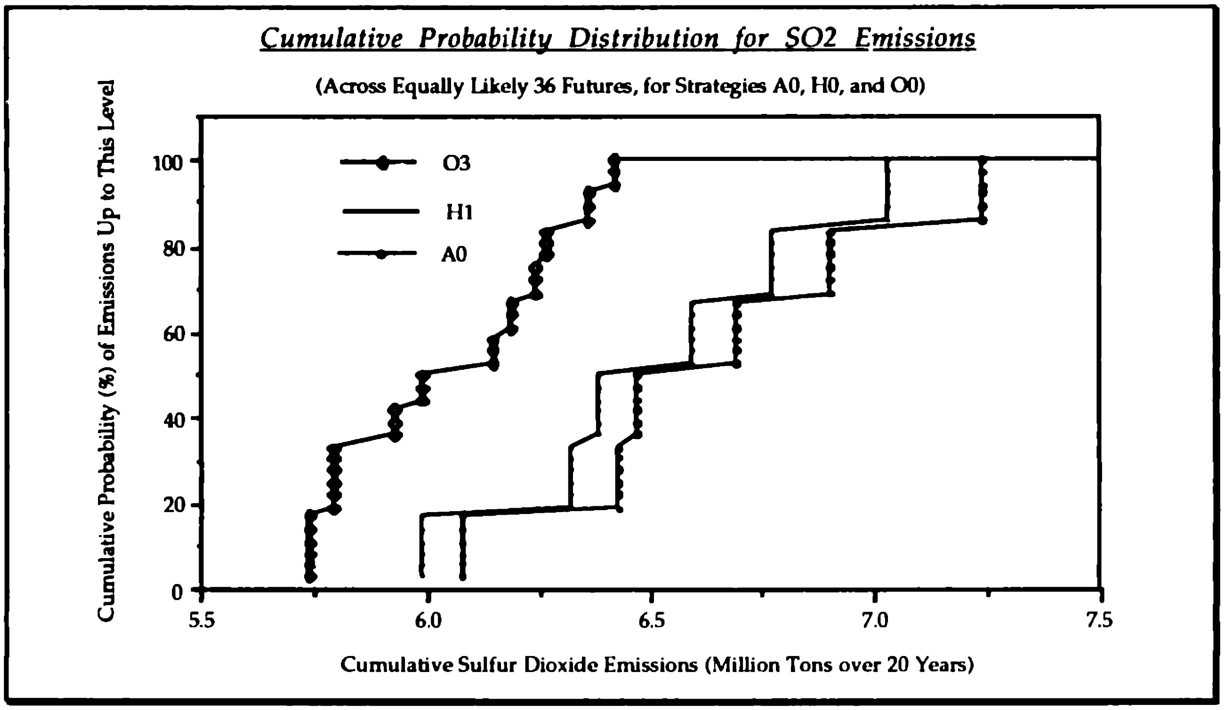
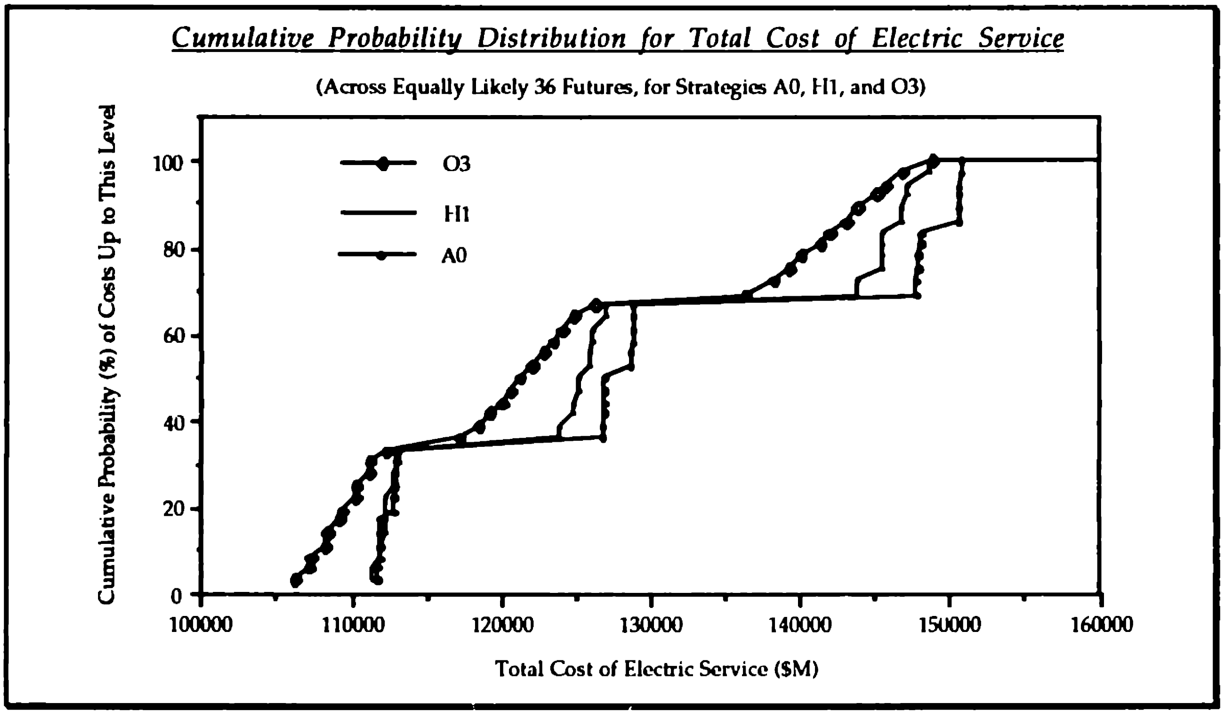


Figure 7-4: Cumulative Probability Distributions of Total Costs by Strategy



A short computer program was developed to quickly sort the strategies into dominated and non-dominated categories based on the FSD criterion. Considering only two attributes – SO_2 emissions and total cost of electric service – this criterion reduced the set of non-dominated strategies to 28. Note that this screen had a much finer mesh than the previous one – while absolute dominance could not screen out any strategies, FSD let less than half of them through. This provided a much smaller decision set upon which to focus tradeoff discussions.

The addition of a third attribute (CO_2 emissions) to the FSD measure left a much larger number of strategies –38 – in the non-dominated set. A fourth attribute (O.P. 4 Level 13 Emergency Hours) pushed the size of the non-dominated set up to 56 strategies out of the total of 60. Thus the FSD sort was useful for focusing on a small decision set worth arguing about only when a very small number of attributes was considered. However, the four-attribute FSD sort had value in identifying strategies that should definitely be kept off of the table – the dominated strategies A0, A1, D2, and F0.

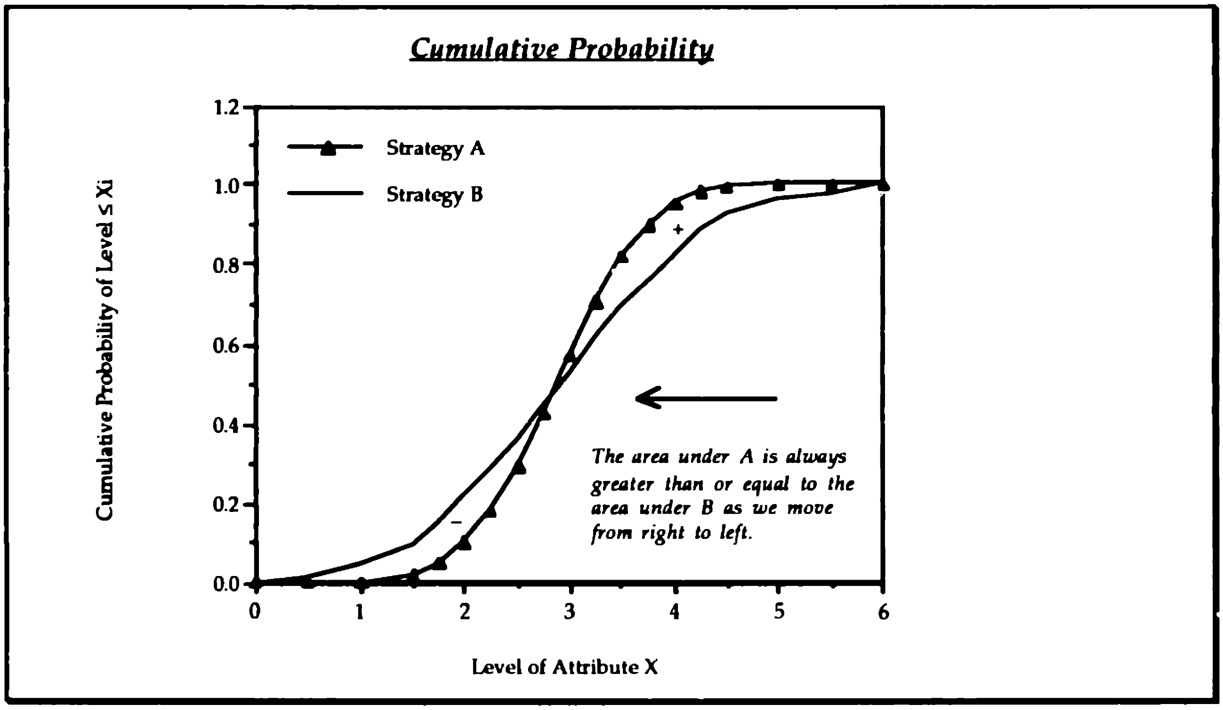
4.a.iii. Assuming risk-aversion, how does the decision set change?

Test for Second Stochastic Dominance, giving all futures equal probabilities, and assuming risk aversion.

Adding to the normative content of the analysis, it was next assumed that all stakeholders had concave utility functions, implying risk aversion. This allowed a sort based on Second Degree Stochastic Dominance (SSD). Levy and Sarnat (1984, Appendices 6.1 and 6.2) proved the optimality of this and the FSD criteria for the case of increasing utility functions. For the case of decreasing utility functions, option A would dominate option B for all risk averters if and only if the area under the cumulative distribution of A exceeded the area under the cumulative distribution of B for all values of attribute X as one progressed from high to low values of X_i. See Figure 7-5 for a graphical representation of SSD. In mathematical terms, this becomes:

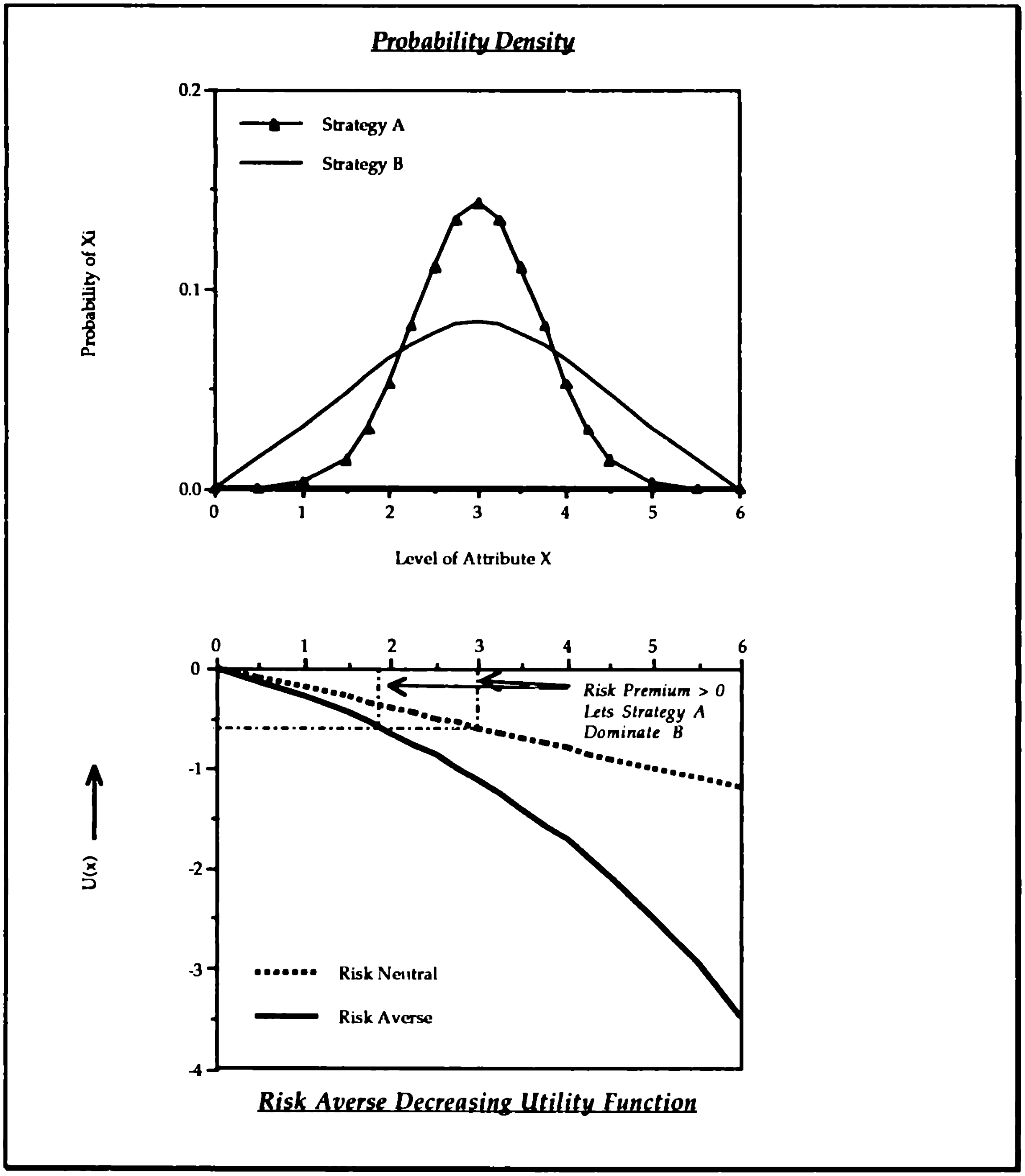
$$\int_{\infty}^{X_i} CPA(x)\,dx \geq \int_{\infty}^{X_i} CPB(x)\,dx \qquad \text{and > in at least one case,} \quad \text{for all } x_i \text{ between } \infty \text{ and } 0. \qquad (7.1)$$

Figure 7-5: Second Stochastic Dominance of Strategy A over B



As Figure 7-6 shows, a decreasing utility function (that shown has the form $U(x) = 3 - .58\ e^{-.25x2}$) that includes any amount of risk aversion requires a risk premium to achieve the same utility level that a risk neutral party would enjoy for the expected value of attribute X. Even though the two strategies A and B have the same expected value (both of their means = 3), the wider variance of B implies that it is a riskier strategy. It therefore provides even minimally risk averse parties with less utility than strategy A. Because of risk aversion, strategy B's high probability (relative to strategy A) of high levels of attribute X weighs more heavily against it than the symmetrical high probability of low levels of attribute X helps it.

Figure 7-6: SSD of Strategy A over B with Decreasing Utility Function



Since risk aversion – in some amount – is a widely shared preference, it is a value judgement likely to be of interest to many of the participants in the planning process. It thus provides a sound basis for a sorting criterion.

Figure 7-7 shows the cumulative probabilities of total cost of electric service for two strategies on the New England project, assuming that all futures are equally likely. Visual inspection of the curves shows that strategy F0 may not be said to dominate E2 under either the Absolute or First Stochastic Dominance criteria, because E2 has a higher cumulative probability at some levels of cost than F0. However, using SSD as the decision rule, strategy F0 can be said to dominate E2 along the cost attribute, because the accumulated area under the curve (going from right to left in Figure 7-7) for F0 is greater than that under E2 for every level of cost.

In order to calculate the area under the cumulative probability curve, it was necessary to slice the data into bins by attribute value instead of by future (its original form). Figure 7-8, for example, was created by calculating the cumulative probability of a strategy falling into each of 36 different total cost bins, starting with the the maximum cost in the entire scenario set, and decreasing in 36 increments of 1350 ($M) down to the minimum cost in the entire set. The quantity 36 was chosen to ensure the same level of detail provided in the original data. The cumulative probability of each bin times the width of each bin gives the rectangle under the curve represented by that bin. Adding them together approximates the area under the curve. In practice, the integrals in equation (7.2) become summations as follows:

$$\sum_{\max x_i}^{x_i} \mathrm{CPA}(x)\,\Delta x \geq \sum_{\max x_i}^{x_i} \mathrm{CPB}(x)\,\Delta x \qquad \text{and} > \text{in at least one case} \qquad (7.2)$$

for all x_i between max x_i and min x_i,
where $\Delta x = (\max x_i - \min x_i)/36$ bins

Figure 7-7: Strategies F0 and E2 – A Difficult Comparison

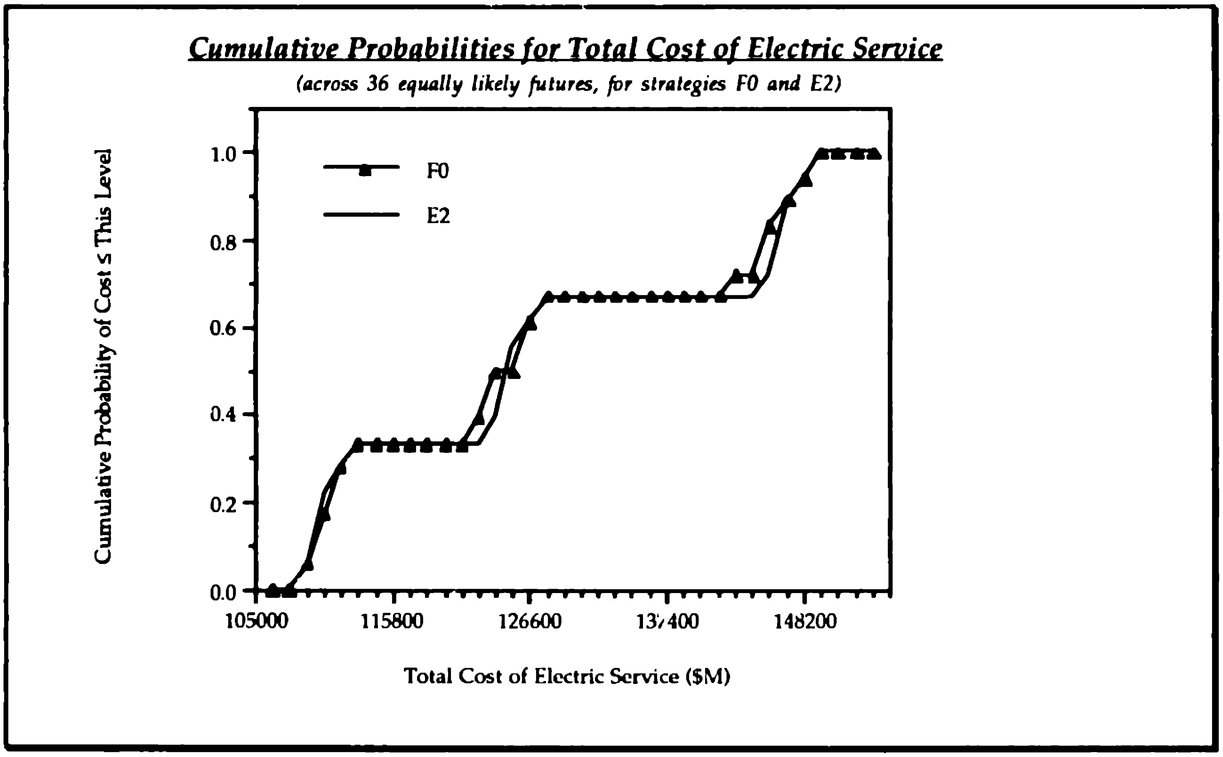
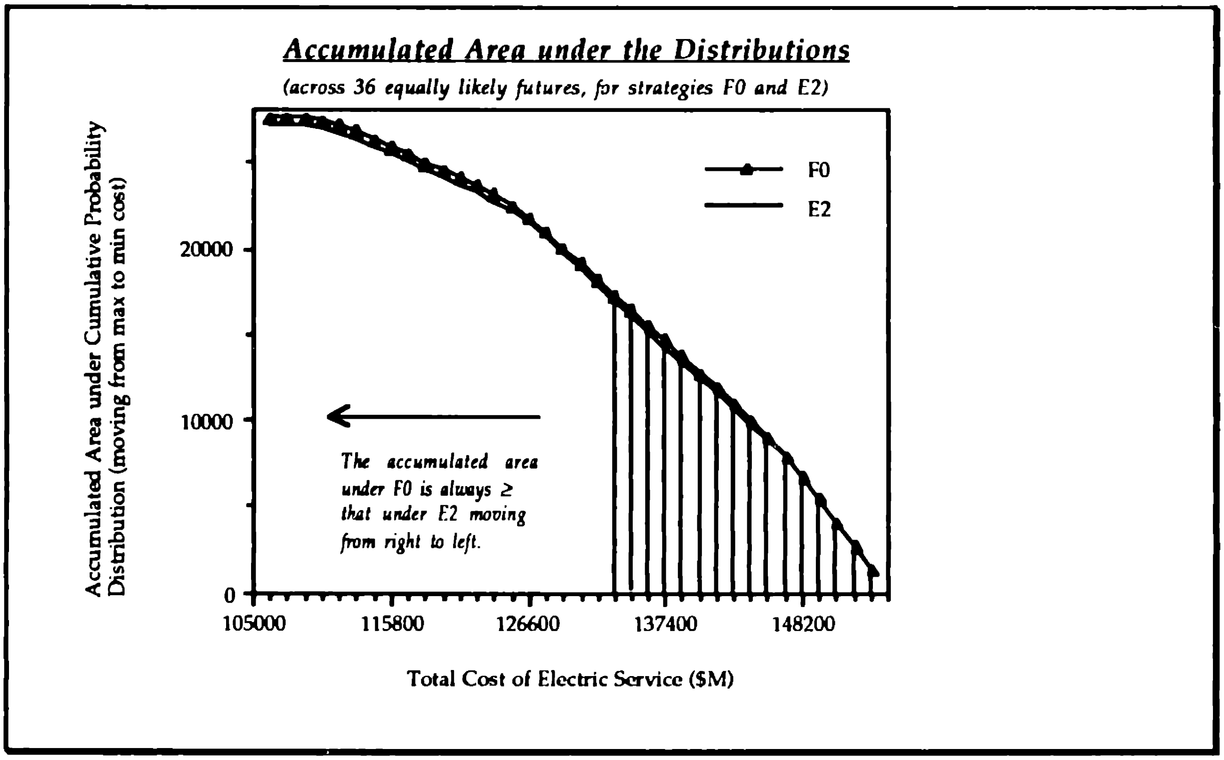


Figure 7-8: Second Stochastic Dominance of Strategy F0 over E2



By developing a computer program to sort strategies by the SSD criterion across the two attributes of total cost and sulfur dioxide emissions, it was possible to screen a significant proportion of them from the non-dominated set. Only 16 strategies were non-dominated (compared to 28 using FSD, and 60 using AD). As with previous criteria, more attributes reduced the effectiveness of the sort. The data manipulation for the SSD sort was quite time consuming, so a short-cut approximating this sort was developed as part of this research (see Figure 7-9). The SSD criterion was approximated by the use of strategy-specific summary statistics, i.e., option A dominated option B (across all futures, for attribute X) if its mean or expected value (E) was less, the maximum value of A was less than that for B, and similarly, the minimum value for A was less than that for B, that is:

$$E(A) \leq E(B) \ \underline{\text{and}} \ \text{Max } A \leq \text{Max } B \ \underline{\text{and}} \ \text{Min } A \leq \text{Min } B \text{ for } X \qquad (7.3)$$

Using summary statistics similar to those generated in the previous chapter, but this time for strategy-specific cohorts, the table shown in Table 7-3 was generated. This six-way screen (mean, maximum, and minimum each for the two attributes of SO_2 emissions and cost) showed several things. First, for each attribute there were clearly dominant and just as clearly dominated strategies. For SO_2, five of the dominant strategies are A2, B2, E2, C2, and D2, while five of the dominated strategies are M0, J0, O0, H0, and L0. This echoed previous findings that repowering-based strategies (2, 3) typically dominated gas-dependent ones (0, 1) for SO_2 emissions. For total cost of electric service, five of the dominant strategies were O0, O1, O3, O2, and K0, while five of the dominated strategies were A3, A2, A1, A0, and D2. This reflected previous findings that high-DSM strategies (K, ...O) had consistently lower costs than low-DSM strategies (A, B,...). However, it appeared that many of the best strategies for reducing SO_2 emissions were the worst along the cost axis (A2 and A3, for example). This did not mean that a two-attribute SSD approximation was restrictive to the point of uselessness. Instead, it pointed out that intermediate strategies were likely to be the most interesting. One intermediate strategy (O3) is shown in Table 7-3. It includes SO_2-reducing repowering on the supply side, and cost-reducing high-DSM on the demand-side. As can be seen by examining all six columns, strategy O3 dominates strategies B1, D1, A1, C1, I1, N1, L1, J1, B0, C0, D0, A0, N0, F0, M1, I0, L0, H0, J0, and M0.

Another computer program was developed to sort the strategies into dominated and non-dominated categories based on this criterion for the attributes of SO_2 emissions and total cost of electric service. Non-dominated strategies – the decision set worth arguing about – included 18 strategies, only two more than the strict SSD criterion. This approximation thus provided similar results to the original criterion, in terms of both the number and types of strategies selected. The success of this short-cut criterion in approximating a true SSD sort is likely to be context-dependent: the data probably need to have a fairly normal distribution. A mathematical exploration of the limits of usefulness of this criterion might be a worthwhile piece of future research.

Figure 7-9: Approximating Distributions with Summary Statistics

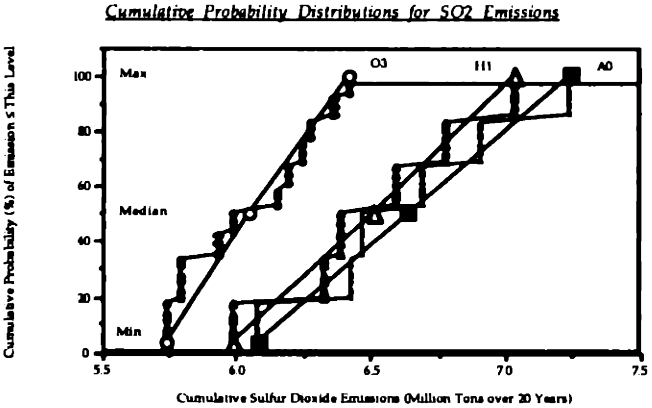


Table 7-3: Sample Means, Maxima, and Minima by Strategy

Strategies shown in ascending order of values for each statistic.

SO2 (Million Tons)				Total Cost of Elect.Svc. (MM$)		
Mean	Max	Min		Mean	Max	Min
A2	A2	E2	*Dominant*	O0	G1	O3
B2	B2	B2		O1	G0	O0
E2	H2	A2		O3	E0	O2
C2	E2	B3		O2	E1	O1
D2	C2	C2		K0	O0	G1
A3	D2	D2		G1	O1	G0
B3	A3	A3		G0	K1	G3
H2	B3	G2		K1	H1	N0
F2	I2	D3		K3	K0	K0
G2	E3	F2		N0	F1	G2
D3	C3	H2		M0	O3	N2
I2	F2	I2		G3	C0	N1
C3	G2	C3		N1	H0	N3
E3	D3	E3		M1	F0	K1
J2	H3	K2		E0	K3	K2
F3	J2	J2		K2	G3	K3
K2	G3	L2		M3	C1	M3
L2	I3	F3		N3	E2	M0
N2	F3	N2		E1	B0	M2
H3	L2	G3		G2	B1	E0
G3	K2	M2		N2	G2	M1
I3	N2	H3		M2	O2	E1
M2	K3	I3		J0	M1	E3
J3	J3	J3		F0	E3	F3
K3	N3	O2		F1	J1	F1
L3	L3	K3		J1	M0	E2
N3	M2	L3		I0	I1	F0
O2	O2	N3		I1	N1	L0
M3	M3	M3		E3	K2	J0
O3	O3	O3		J3	H3	I0
B1	E1	I1		E2	J0	F2
E1	B1	B1		L0	N0	L1
D1	G1	N1		L1	C2	L3
A1	D1	K1		C0	M3	L2
C1	C1	J1		H0	B2	J1
G1	A1	E1		J2	I0	J3
I1	F1	N0		I3	H2	I1
F1	K1	E0		F3	F2	D3
N1	I1	H1		L3	A1	J2
K1	N1	L1		H1	F3	I3
H1	H1	K0		C1	J3	D0
L1	L1	D1		B0	A0	I2
E0	J1	A1		F2	N3	C0
J1	O1	C1		B1	D1	D1
B0	B0	G1		I2	D0	B0
C0	G0	D0		D0	C3	C1
D0	E0	B0		L2	M2	B1
G0	M1	L0		D1	L1	C3
O1	C0	C0		H3	I3	D2
A0	A0	A0		C2	L0	B3
N0	F0	I0		C3	J2	C2
F0	D0	O1		H2	A2	B2
K0	H0	G0		B2	B3	H0
M1	O0	O0		B3	N2	H3
I0	I0	J0		D3	I2	H1
L0	N0	F1		D2	D2	H2
H0	L0	M1		A0	L3	A0
O0	K0	F0		A1	A3	A1
J0	M0	H0		A2	D3	A3
M0	J0	M0	*Dominated*	A3	L2	A2

Table 7-4: Dominated and Non-dominated Strategies under AD, FSD, SSD and Summary Statistics Decision Rules

Sixty strategies evaluated across thirty-six equally likely futures for two attributes – Total Cost and SO2 Emissions.

Absolute Dominance		First Stochastic Dominance		Second Stochastic Dominance		Summary Statistics Dominance	
Dominated	Non-dominated	Dominated	Non-dominated	Dominated	Non-dominated	Dominated	Non-dominated
	A0	A0		A0		A0	
	A1	A1		A1		A1	
	A2		A2		A2		A2
	A3	A3		A3		A3	
	B0	B0		B0		B0	
	B1	B1		B1		B1	
	B2		B2		B2		B2
	B3	B3		B3		B3	
	C0	C0		C0		C0	
	C1	C1		C1		C1	
	C2		C2		C2	C2	
	C3	C3		C3		C3	
	D0	D0		D0		D0	
	D1	D1		D1		D1	
	D2	D2		D2		D2	
	D3	D3		D3		D3	
	E0		E0	E0			E0
	E1		E1		E1		E1
	E2		E2		E2		E2
	E3		E3	E3			E3
	F0	F0		F0		F0	
	F1	F1		F1		F1	
	F2		F2	F2		F2	
	F3	F3		F3		F3	
	G0		G0		G0	G0	
	G1		G1		G1		G1
	G2		G2		G2		G2
	G3		G3		G3		G3
	H0	H0		H0		H0	
	H1	H1		H1		H1	
	H2		H2		H2		H2
	H3	H3		H3		H3	
	I0	I0		I0		I0	
	I1	I1		I1		I1	
	I2		I2	I2		I2	
	I3		I3	I3		I3	
	J0	J0		J0		J0	
	J1	J1		J1		J1	
	J2		J2	J2		J2	
	J3	J3		J3		J3	
	K0		K0	K0			K0
	K1		K1	K1			K1
	K2		K2		K2		K2
	K3		K3		K3		K3
	L0	L0		L0		L0	
	L1	L1		L1		L1	
	L2		L2	L2		L2	
	L3	L3		L3		L3	
	M0	M0		M0		M0	
	M1	M1		M1		M1	
	M2		M2	M2		M2	
	M3	M3		M3		M3	
	N0	N0		N0		N0	
	N1	N1		N1		N1	
	N2		N2	N2		N2	
	N3		N3	N3		N3	
	O0		O0		O0		O0
	O1		O1		O1		O1
	O2		O2		O2		O2
	O3		O3		O3		O3

As the normative content of the sorting criteria increased, their effectiveness at screening strategies out of the non-dominated set also increased. Table 7-4 summarizes the progression. Most of the non-dominated strategies were identified previously in the graphical analysis of Chapter Six. A look at Figure 6-30, showing the average values of cost and SO2 emissions for each strategy, confirms that these non-dominated strategies are the same as those lying on or near the frontier in the scatter plot.

4.a.iv. Emphasizing different futures, how does the decision set change?

Review the future-specific performance of the strategies.

The next increment of increased normative content involved different generic rules for dealing with uncertainty. Until this point all futures were assumed to be equally probable. Now their probabilities changed. Four different generic rules were examined:

1.) base case (most probable future in analysts' judgement)

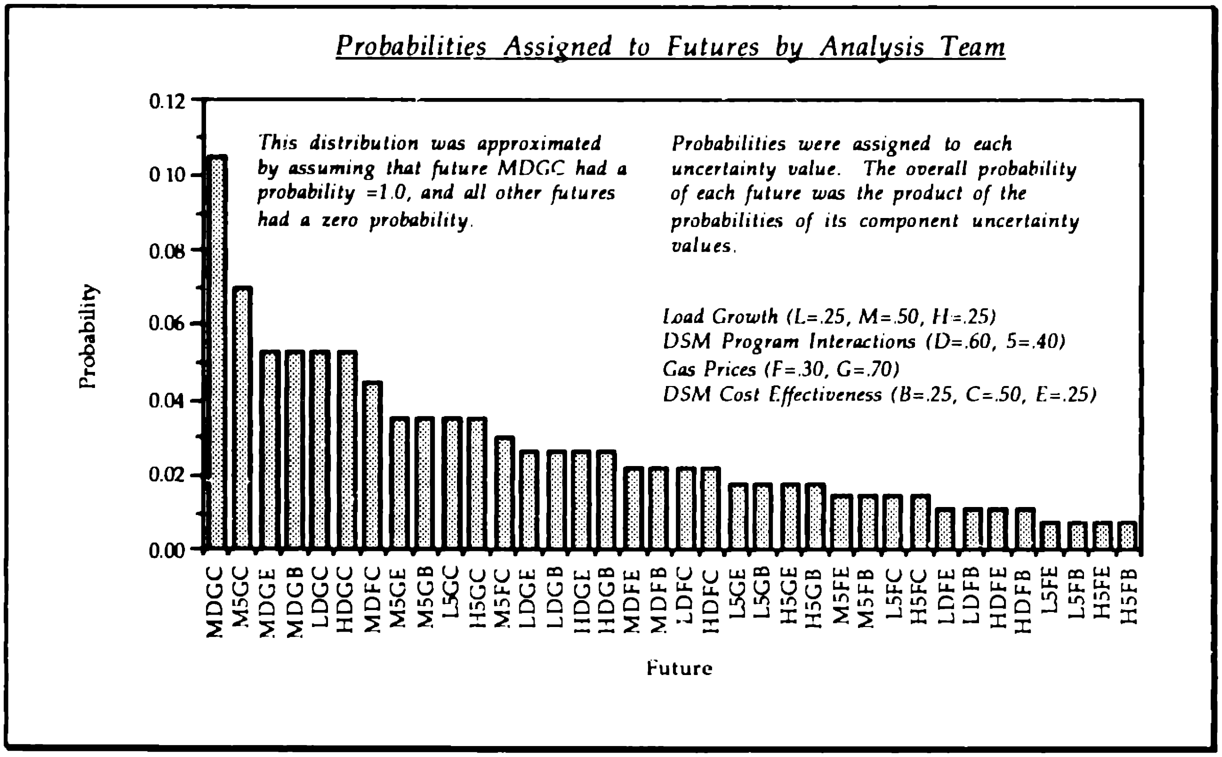
2.) maximin (extreme risk aversion: minimize down-side risk by assuming that the worst future is most probable)

3.) maximax (extreme optimism: maximize up-side benefits by assuming that the best future is most probable)

4.) minimax regret (extreme accountability: minimize the range of outcomes by assuming that both the best and worst futures are highly probable, and select strategies with small differences between the two)

A set of more refined SSD sorts could have been made using different probability assignments for the various futures, instead of assuming that they were all equally likely, as above. However, instead of adjusting the probabilities of all of the futures and then assessing the cumulative probability distribution, future-specific attribute values were directly used. This short cut was feasible because the uncertainties and option sets had been exhaustively combined when designing the scenario set, thus all strategies could be evaluated for every possible combination of uncertainty values. For the base case assumed most probable by the analysts, the difference between using the cumulative distribution and the deterministic data for the single most probable future is shown in Figure 7-10. Most probable future MDGC was assigned a probability of 0.105 but was modeled as being certain (1.000).

Figure 7-10: Assignment of Future MDGC as the Base Case



The non-dominated set for the future MDGC (considering cost and SO_2 emissions) included eleven strategies, substantially fewer than any of the previous sorts. They were a subset of the SSD decision set (see Table 7-4).

The maximin sort assumed that the worst future was the most probable one. Figure 6-34 in Chapter Six showed that future. As can be seen, the non-dominated set for cost and SO_2 emissions included ten strategies (see Table 7-5), three of which (A3, B3, and D3) were not in the SSD decision set.

The maximax sort assumed that the best future was the most probable one. As we recall from Chapter Six, there were two different best futures, one for cost (LDFB, see Figure 6-35) and one for SO_2 emissions (HDFB, see Figure 6-36). In the best future for cost there were eight non-dominated strategies: A2, B2, E2, I2, K2, N2, O2, and O3. The best future for SO_2 emissions had ten non-dominated strategies: A2, B2, E2, G2, K2, N2, O0, O1, O2, and O3. The maximax decision set consisted of the union of these two sets.

The minimax regret sort assumed that both the best and worst futures were highly probable, and sought to minimize the difference between them. For cost, the difference between futures H5GE and LDFB was minimized; for SO_2 emissions it was the difference between futures H5GE and HDFB. A computer program screened the strategies according to the following rule:

$$\text{A dominates B iff } \Delta \text{Cost}_A < \Delta \text{Cost}_B \text{ and } \Delta SO_{2A} < \Delta SO_{2B} \qquad (7.4)$$

This sort resulted in an extremely small non-dominated set consisting of only five strategies (see Table 7-5). Of these, only strategy A2 appeared in any of the previous decision sets. This decision rule thus revealed itself to sacrifice efficiency for consistency. It was equivalent to screening strategies on the basis of standard deviation alone, with no thought for the average result. It is interesting to note that this was the only decision rule that selected the strategy most similar to the utility companies' status quo – current utility conservation programs, power purchases, and gas-dependent technology (H1).

Table 7-5: Dominated and Non-dominated Strategies under Most Probable, Maximin, Maximax and Minimax Regret Decision Rules

Sixty strategies evaluated across specific futures for two attributes - Total Cost and SO2 Emissions.

Most Probable Future		Maximin (worst future)		Maximax (best future)		Minimax Regret (Δbest-worst)	
Dominated	Non-dominated	Dominated	Non-dominated	Dominated	Non-dominated	Dominated	Non-dominated
A0		A0		A0		A0	
A1		A1		A1		A1	
	A2		A2		A2		A2
A3		A3		A3			A3
B0		B0		B0		B0	
B1		B1		B1		B1	
	B2		B2		B2	B2	
B3			B3	B3		B3	
C0		C0		C0		C0	
C1		C1		C1		C1	
	C2		C2	C2		C2	
C3		C3		C3		C3	
D0		D0		D0		D0	
D1		D1		D1		D1	
D2		D2		D2		D2	
D3		D3		D3		D3	
E0		E0		E0		E0	
E1			E1	E1		E1	
	E2		E2		E2	E2	
E3		E3		E3		E3	
F0		F0		F0		F0	
F1		F1		F1		F1	
F2		F2		F2		F2	
F3		F3		F3		F3	
G0		G0		G0		G0	
G1			G1	G1		G1	
	G2	G2			G2	G2	
	G3		G3	G3		G3	
H0		H0		H0		H0	
H1		H1		H1			H1
H2		H2		H2			H2
H3		H3		H3			H3
I0		I0		I0		I0	
I1		I1		I1		I1	
I2		I2			I2	I2	
I3		I3		I3		I3	
J0		J0		J0		J0	
J1		J1		J1		J1	
J2		J2		J2		J2	
J3		J3		J3		J3	
K0		K0		K0		K0	
K1		K1		K1		K1	
	K2	K2			K2	K2	
	K3		K3	K3		K3	
L0		L0		L0		L0	
L1		L1		L1		L1	
L2		L2		L2		L2	
L3		L3		L3		L3	
M0		M0		M0		M0	
M1		M1		M1		M1	
M2		M2		M2		M2	
M3		M3		M3		M3	
N0		N0		N0		N0	
N1		N1		N1		N1	
N2		N2			N2	N2	
N3		N3		N3		N3	
O0		O0			O0	O0	
	O1	O1			O1	O1	
	O2	O2			O2	O2	
	O3		O3		O3	O3	

Many of the same strategies appeared in each of the future-specific dominance sorts above. This confirmed their importance for the tradeoff discussions, because, regardless of both uncertainties and the decision rules for dealing with uncertainty, these strategies remained present in the decision set. Strategies surviving all of the dominance sorts (excluding minimax regret) included A2, B2, E2, and O3. Only strategy A2 survived all of the sorts. All of them enjoyed the repowering supply option (2,3) in common.

4.a.v. Emphasizing different attributes, how does the decision set change?

Review the attribute-specific performance of the strategies.

Single attribute sorts represented a next logical step in increasing the normative content of the decision rules. These bracketed the actual preference mappings of the participants, who would ultimately have to balance multiple attributes. Since attributes formed the basis for specifying preferences, it was useful to review the performance of the strategies one attribute at a time under the different uncertainty-related decision rules.

Table 6-4 in Chapter Six summarized the strategy rankings along several attributes, based on rank sums across 36 equally weighted futures. Table 7-6 provides similar information for the specific futures analyzed above.

Table 7-6 shows that four out of the five top ranked (on average) strategies for SO_2 reductions remained in the top five across all three specific futures – most probable, worst, and best. Only one of the top cost-reducing strategies survived across all three futures. The general characteristics of the best strategies – repowering for SO_2 reductions, and high conservation for cost reductions – remained more consistent.

Table 7-6: Top Ranked Strategies along Two Attributes for Specific Futures

Sulfur Dioxide Emissions

Average of Futures	Most Probable	Maximin (worst)	Minimax (best)
A2	A2	E2	E2
B2	B2	B2	B2
E2	C2	B3	A2
C2	E2	A2	B3
D2	D2	C2	C2

Total Cost of Electric Service

Average of Futures	Most Probable	Maximin (worst)	Minimax (best)
O0	O1	G1	O3
O3	O3	G0	O0
O1	O0	E0	O2
G1	O2	E1	O1
K0	K0	O0	G0

Step 4.b. Elicit stakeholder values.

The next step in increasing the normative content of the analysis was to take the points of view of specific stakeholders. In order to do this, their preferences had to be elicited. In the original conception of this research it was proposed to construct utility functions to simulate stakeholders' preferences while analyzing mediation strategies. This could have improved the efficiency of a time-constrained negotiating process. Unlike other decision analysis methods which used utility functions to allow mechanical choice-making, or optimization, they would have been used here only to suggest possibly fruitful negotiating directions. The decision making power would have remained in the hands of the participants.

Because utility functions would have been constructed to simulate the preferences of a large number of stakeholders across many options and considering many attributes, a fairly simple formulation was originally proposed. An additive form would have been used for the overall utility function for each stakeholder, as follows:

$$u_i(X) \quad = \quad \sum_j k_{ij}\, u_{ij}(x_{ij}) \quad , \qquad \text{with} \ \sum_j k_{ij} = 1 \qquad (7.5)$$

where
i = stakeholder i
k_{ij} = stakeholder i's scaling constant for utility derived from attribute j
$u_{ij}(x_{ij})$ = stakeholder i's utility function for level x of attribute j

This formulation implied the fairly restrictive assumption of additive independence among attributes. While this assumption was unrealistic for cases where attributes were either complements or substitutes for one another, the additive formulation would have sufficed for the fairly approximate estimations required in this application.

It was also thought that the attribute-specific utility function needed to capture the effects of uncertainty on the attractiveness of an option. The utility function in Figure 7-6 showed one way to do this. It was an exponential formulation ($U(x) = a - b\, e^{-.25x2}$) with two important characteristics: (1) utility decreased as attribute levels increased, and (2) it displayed risk aversion. The expected utility could be calculated using the probability distributions of attribute values developed earlier for each strategy.

Further steps could have been taken down this road, with the analysts eliciting specific probabilities to assign to each future, plus utility function parameters allowing the preferences of the participants in the advisory group to be precisely modeled. The theoretical underpinnings of such activities were well established (see Keeney & Raiffa, 1976, for example) and the additional computational burden would have been manageable. However, two factors, one theoretical and one practical, turned the research away from this traditional utility assessment approach.

The theoretical problem was based on the fact that the participants' preferences (and expectations of future events) were moving targets. As new information was provided to the group, the nuances of their value judgements changed. New information generated by their growing understanding of the behavior of the electric power system (the third step in the open planning framework) rapidly made the details of their previously elicited preference mappings obsolete. Detailed quantitative analysis using the participants' preferences was always mooted by the learning dynamic. At the broad brush level of multi-attribute prioritization the preferences were relatively consistent. However, at the detailed level of marginal rates of substitution among attributes, and rates of change in risk aversion, this could not be the case.

The practical factor steering the research away from detailed preference elicitations was time. The marginal benefit of that activity to the process was perceived to be much lower than that of time invested in direct communications among the parties. The participants thought they gained more from directly observing each others' preferences than they would have from lengthy individual interviews with the analysts. Indeed, since the development of a public consensus on power industry issues was necessary before the planning paralysis could be overcome, it was felt to be more important for the analysts to be on the road sharing results with a wider audience than it was for them to capture the details of a dozen decision makers' current preferences.

There are strong arguments against this point of view. For example, Keeney and Raiffa (1976, pg. 17) point out that careful utility analysis forces people to think harder about the problem at hand than they might otherwise, that it forces them to become more consistent in their preferences, and helps them reach defensible decisions in the face of complexity and uncertainty where, without formal utility analysis, their minds would boggle. These arguments, which focus primarily on the needs of a single decision maker, must be balanced against those marshalled above for the group decision making context.

The participants' preferences were not ignored during analysis in the New England project. Instead of conducting detailed utility assessments for each of the stakeholders, a simplified approach was used. A questionnaire allowed them to prioritize attributes and uncertainties. Interactions during the multi-attribute presentations graphically revealed where along the cost vs. SO_2 tradeoff curve individuals preferred to be. Future-specific results allowed participants to review the performance of strategies under future conditions considered most probable by each of them. These steps are discussed in more detail below.

4.b.i. How do different parties prioritize attributes?
Elicit the participants' views in a questionnaire.

The January, 1990 questionnaire asked the New England project advisory group members about their preferences. They were asked to prioritize issues, uncertainties, attributes, demand-side option sets, and supply-side option sets. Their responses revealed consistency in some areas, and strong differences of opinion in others. Table 7-7 summarizes the results.

Table 7-7: What Attributes Are Most Important to You?
(Considering the Effects of Uncertainty)
Top Five New England Project Questionnaire Responses

Attribute	Collective Priority	Range
Reliability	1	1 – 2
Cost of Electricity	2	1 – 4
Environmental Impacts	3	1 – 3
Investment Levels	4	1 – 4
Fuel Diversity	5	2 – 5

The responses showed strong consistency regarding the importance of reliability, somewhat less consistency regarding environmental impacts, and even less for costs, investment levels, and fuel diversity. Since there were tough cost versus environment tradeoffs among strategies, these differences in the respondents preferences were quite important.

4.b.ii. How do different parties view uncertainty?

Elicit the participants' views in a questionnaire.

The same January, 1990 questionnaire asked the advisory group members about different uncertainties. The results are shown in Table 7-8.

Table 7-8: What Uncertainties Concern You Most?
Top Five New England Project Questionnaire Responses

Uncertainty	Collective Priority	Range
Fuel Price and Availability	1	1 – 3
Load Growth	2	1 – 3
DSM Impacts/Effectiveness	3	1 – 5
Changing Environmental Regulations	4	1 – 4
Changes in Demand and Load Shape	5	1 – 4
Investment Costs	5	1 – 4

There was more agreement on the importance of fuel-related and load growth uncertainties than for the others shown above. Several uncertainties were extremely important to one participant but not to others. For example, supply capacity performance did not receive enough votes to be ranked among the top five, but it was given first priority by the chairman of one state's Public Utility Commission.

4.b.iii *How do different parties view the various strategies? Elicit the participants' views in a questionnaire.*

Additional questions on the January, 1990 questionnaire asked advisory group members what they thought the best strategies were for the region. They were first queried about demand-side activities, and then about the supply-side. This was done in a questionnaire rather than during the advisory group meeting in order to prevent participants from having to publicly "own" the strategies they recommended. The results are summarized in Tables 7-9 and 7-10.

Table 7-9: Which Demand-Side Strategies
Are the Best Ones for the Region to Follow?
Top Five New England Project Questionnaire Responses

Strategy	Collective Priority	Range
Market-driven DSM	1	1 – 4
Utility-sponsored DSM	2	1 – 4
Energy Efficiency Standards	3	1 – 4
Tax Credits for Efficiency	4	2 – 5
Collaborative DSM Programs	5	1 – 1

Table 7-10: Which Supply Strategies Are Best for the Region to Follow?
Top Five New England Project Questionnaire Responses

Strategy	Collective Priority	Range
Repower Existing Plants	1	1 – 3
Life-Extend Existing Plants	2	1 – 5
Build New Gas-Fired Capacity	3	1 – 4
Purchase Power from Canada	4	1 – 5
Build New Nuclear Capacity	5	1 – 5

There was a very large range of answers to these questions, even among highly ranked strategies. Differences of opinion clearly existed. However, many of the advisory group members modified their opinions about supply-side strategies during the period between the initial questionnaire in June, 1989 and the one in January, 1990. By the time of the later questionnaire, interim results of the scenario analysis had been shared with the group. The strong showing of the repowering option, and the weak showing of the gas-dependent option in that data set appears to have influenced their preferences. Table 7-11 summarizes both the 1989 and 1990 preferences of the advisory group members who responded to both surveys, for the top three supply strategies.

Table 7-11: Comparison of 1989 and 1990 Questionnaire Responses
(priorities based on rank sums)

Strategy	1990 Priority	1989 Priority
Repower Existing Plants	1	3
Life-Extend Existing Plants	2	1
Build New Gas-Fired Capacity	3	2

Thus the group seemed to be engaged in a collective learning process, and their preferences responded to the new information provided by the analysis. However, as of January, 1990, there was no clear consensus on the path that New England should take in meeting its future electric service needs.

Step 4.c. Undertake conflict analysis.

Conflict assessment is beginning to enjoy formal development as an analytic tool (Lee & Wiggins, 1989). It is viewed as a vital analytic task that supports the process of consensus-building, and of discovering all-gain options, without requiring the aggregation of individual utility functions into a single optimizable social welfare function. It is intended to help the neutral party in a negotiation discover what different parties are willing to trade, where are their gaps and overlaps regarding preferred strategies, and what are the characteristics of strategies with the potential for consensus. Armed with this information, the neutral party may be able to more effectively guide the stakeholders in the negotiation to consensus.

The January, 1990 questionnaire results helped to identify both the areas of conflict and possibilities for common ground in the New England project. Each area is briefly discussed below.

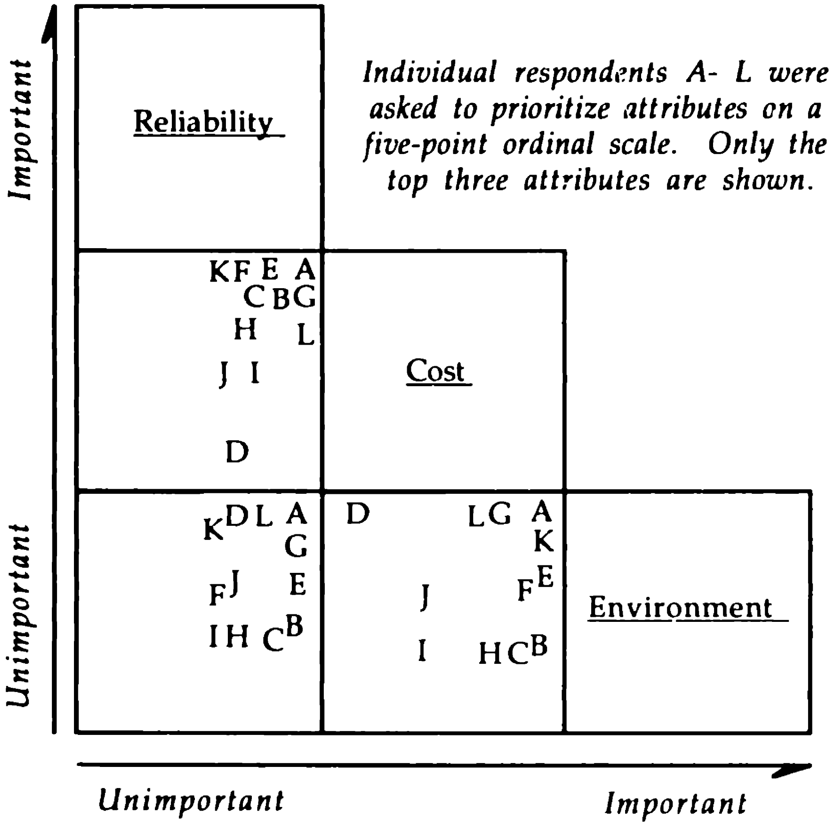
4.c.i. What are the areas of conflict?

Evaluate the clustering of stakeholders' preferences in multi-attribute space.

Figure 7-11 provides a quick glimpse at the priorities of the members of the advisory group who responded to the January, 1990 questionnaire. The parties were asked to ordinally rank attributes on a scale from first to fifth priority. We look here at only the top three attributes in the overall ranking. All of the respondents (labeled A - L for anonymity) felt that reliability was important, so no conflicts existed regarding that goal. The wider range of priorities assigned to environmental quality indicated that there was less consensus regarding that attribute. Cost showed an extremely wide range.

Respondent D held the most extreme views relative to the rest of the group, ranking environmental quality high and cost very low. While other respondents shared D's environmental views, they were not willing to sacrifice as much on cost. The most diametrically opposed parties to D were B and C, both of whom cared far less about the environment than about cost. Respondents I and J were relatively apathetic regarding all three of the attributes shown, while respondent A felt strongly about all three attributes in equal measure.

Figure 7-11: Stakeholder Clusters for Three Attributes



This confirmed an unsurprising point, that the areas of greatest conflict were between cost minimizers and environmental damage minimizers. The challenge for the analysts was to develop strategies giving both groups enough of what they wanted to achieve consensus, and to persuade the parties that both points of view could be satisfied.

4.c.ii. *Where is the common ground?*

Conduct future-specific dominance sorts using weighted attributes.

Just as dominance sorts using different generic decision rules such as maximin and maximax produced similar decision sets, so it could be that stakeholder-specific dominance sorts would select some of the same strategies. This was tested using the participants' questionnaire responses and the scenario data. As was done previously, future-specific data were used in lieu of cumulative probability distributions when modeling the effects of uncertainty in the conflict analysis. Once the preferred future (for planning purposes) of a stakeholder was identified, then simple isopreference mappings could be used to simulate choices.

This analysis identified attributes of concern to each party, developed scales and ranges of measurement for each attribute, calculated the multi-attribute impacts, and had the parties prioritize the attributes. A complete utility assessment would have gone on to normalize the attribute scales, elicit value curves for different levels of each attribute, and elicit weights for attributes relative to one another, thereby constructing detailed utility functions (see Ford et al, 1980, for example). In this project the value curves were assumed to be linear on a percent change basis, and the weights were arbitrarily set to equal the attribute's priority level. Thus the marginal rate of substitution (MRS) between cost and environmental impacts was calculated as follows for the two polarized stakeholders B and D:

Cost-minimizer B: Cost attribute = 1st Priority
Environmental attribute = 3rd Priority

MRS_B(Cost/Environment) = -1% Cost/3%Environmental Impact
= \$6/lb SO_2 in area of decision set

Pollution-minimizer D: Cost attribute = 4th Priority
Environmental attribute = 1st Priority

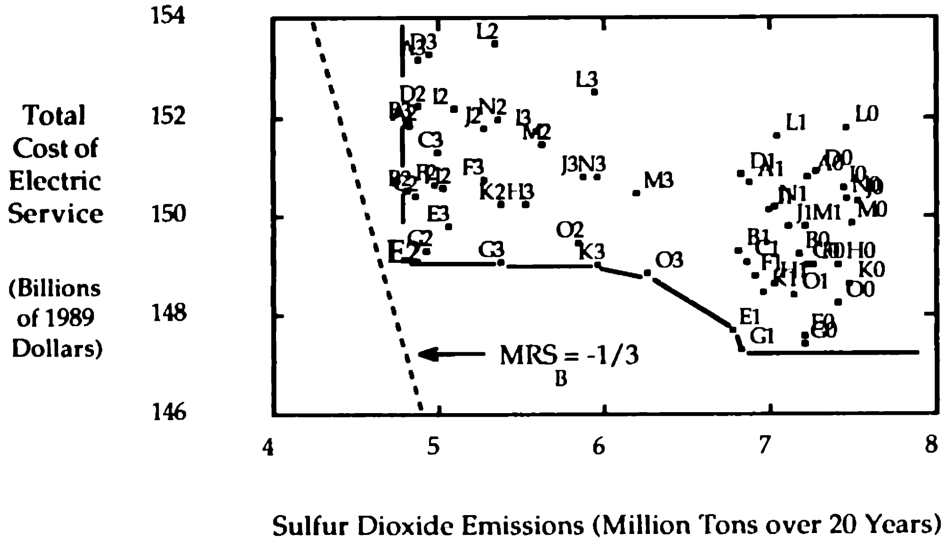
MRS_D(Cost/Environment) = -4% Cost/1%Environmental Impact
= \$65/lb SO_2 in area of decision set

These marginal rates of substitution provided the slopes of indifference lines in two-attribute space. Each indifference mapping was then overlaid on the tradeoff plot for that stakeholder's respective high probability future. The points of tangency of these lines with the tradeoff frontiers identified the most-preferred strategies in this crude simulation of those stakeholders' preferences. Figure 7-12 shows the outcome for stakeholders B and D, using only the attributes of cost and sulfur dioxide emissions.

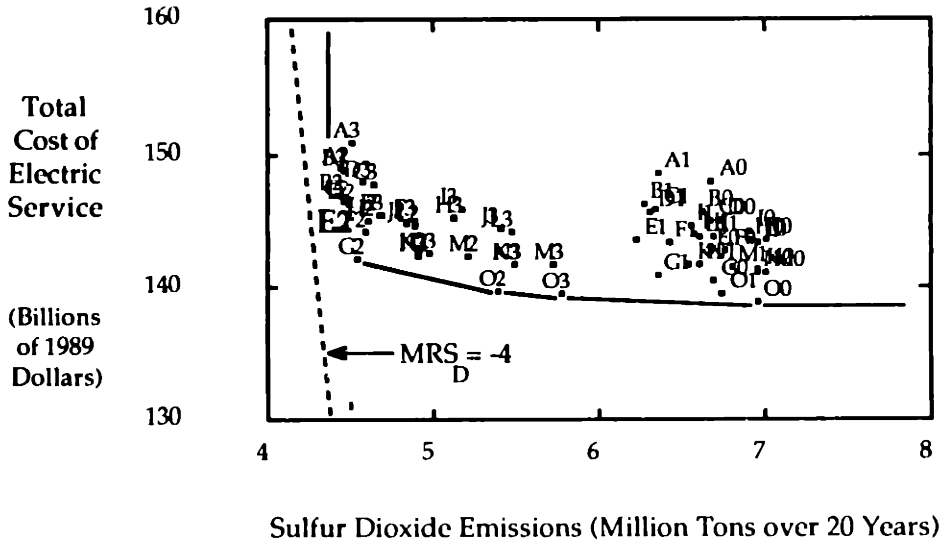
In spite of the dramatically different weights assigned to the attributes and the differing assumptions about future events, strategy E2 showed that it was likely to be preferred by both parties. This confirmed that there was the potential for consensus on strategies to follow in spite of differences of opinion about basic priorities. Much like the generic dominance sorts that led to similar decision sets, so the stakeholder-specific sorts showed overlapping strategy preferences. Externality values extant in the public debate are much smaller than those hypothesized above, ranging from \$0.42 to \$3.50 per pound of SO2 emitted (Chernick & Caverhill (1989), NYDPS (1989)). Thus the real opportunities for agreement are likely to be even greater than suggested here.

Figure 7-12: Developing a Consensus on Strategy "E2"

Performance of Strategies in Future H5GE – Considered Most Probable by Cost Minimizer B



Performance of Strategies in Future H5FB – Considered Most Probable by Pollution Minimizer D



Step 4.d. Invent better strategies.

The information gained about the participants' preferences could have been useful for inventing better strategies. If there had been dramatic non-linearities in peoples' preferences, or if there were unexpected gaps and overlaps that allowed trading, then this could have guided the analysts in proposing alternative strategies. However, the sixty strategies evaluated in this round of the New England project were similar enough that the exercise of understanding the participants' preferences did not yield dramatic new insights. The strategies shown to be dominant in Chapter Six proved that they were dominant under a variety of increasingly normative decision rules in this chapter. However, no new combinations of options suggested themselves for study.

The case evaluated in the next chapter included options with a wider variety of characteristics, some of which –coal and nuclear plants – provoked powerful evidence of nonlinearities in peoples' preference mappings. Later New England data sets are likely to see similar results, making the preference elicitation stage of the analysis more fruitful.

Efficacy of Step Four: Understanding Participants' Preferences

This step in the scenario-based multi-attribute tradeoff analysis framework was designed to test the strategies against the perceptions and preferences of the stakeholders in the planning debate. We sorted through the strategies using decision rules with increasing levels of normative content to arrive at a small, robust decision set. These strategies were shown to be attractive for a variety of individual perceptions about uncertain future events. It was also shown that some strategies could remain attractive to parties with widely different attribute priorities.

While these efforts reinforced our faith in the dominance of some strategies over others, they did not, in this case, provide dramatic new insights about yet better strategies to model. The dynamic effects on parties' preferences as they learned from the exploration of system behavior reduced the value of portions of this step. Further, the debate over tradeoffs among strategies and along several attributes moved at a much quicker pace verbally, during meetings, than could be anticipated analytically. Thus much of the conflict assessment stage produced results so obvious as to be irrelevant.

The efficacies of the specific methods used in understanding the participants' preferences are summarized in Table 7-12.

Step 5. Seek Consensus on a Strategy Preferred by the Group

After spurring the inventiveness of the stakeholders in the planning debate by: (1) exploring the behavior of the electric power system, and (2) understanding the participants' preferences, a better set of strategies should emerge. Some of these may have the potential for consensus. Seeking consensus on a strategy preferred by the group is a way to test this.

The New England project is not yet at that stage. As the 1989 and 1990 questionnaire results showed, there is an increasing convergence around strategies shown by the analysis to be dominant. However, neither the process of exploring the system's behavior nor that of understanding the participants' preferences are complete. The quality of the debate has improved, but it is not yet concluded.

Table 7-12: Efficacy of Methods for Understanding Participants' Preferences
(Initial Framework) as Applied on the New England Project

<u>***Understanding Participants' Preferences (Initial Framework)***</u>	***Useful to Analysis Team?***	***Useful to Advisory Group and Public?***
4.a. Sort through the strategies – slowly add normative content to the decision rules.		
i. Which strategies are dominated by others across all attributes and futures?	Yes	Yes
ii. Which strategies are dominated by others across all attributes, if equal probabilities are assigned to all futures?	Yes	Yes
iii. Assuming risk-aversion, how does the decision set change?	Yes	Yes
iv. Emphasizing different futures, how does the decision set change?	Yes	Yes
v. Emphasizing different attributes, how does the decision set change?	Yes	No
4.b. Elicit stakeholder values.		
i. How do different parties prioritize attributes?	Yes	No
ii. How do different parties view uncertainty?	Yes	No
iii. How do different parties view the various strategies?	Yes	No
4.c. Undertake conflict analysis.		
i. What are the areas of conflict?	No	No
ii. Where is the common ground?	Yes	No
4.d. Invent better strategies.		
i. Are there new packages of options that have more of the characteristics everyone prefers?	No	No
ii. What new strategies have the potential for consensus?	No	No

Overall Efficacy of the Framework on the New England Project

The New England project provided the opportunity to test the scenario-based multi-attribute tradeoff analysis framework in practice, and to experiment with several aspects of the open planning concept. This real life application provided a variety of insights about the efficacy of the process.

The initial structure of the project included an MIT analysis team serving an invitation-only advisory group regional decision makers, with funding from a consortium of New England utilities and businesses. The neutrality of the analysts had to proved to the non-utility parties over a period of several months, but did not seem to hinder the effort over the longer run. Likewise, the exclusive nature of the advisory group membership was more perceived than real – no-one was ever turned away from a meeting.

The technical credibility of the analysis team also had to be proved over a period of several months. This was made easier by the high level of expertise in the advisory group. These people were able to understand the intermediate results, identify technical errors, and confirm the validity of the final results. The analysis technique, which depended on rigorous application of the "scientific method," i.e., careful design of numerous controlled experiments, the use of inductive logic to infer conclusions from sample statistics, and documentation of assumptions, also enhanced the credibility of the technical results.

The first step in the process – identifying issues and attributes – worked quite well in the New England project. Both the analysis team and the advisory group brainstormed long lists of issues, and then succeeded in prioritizing them. This ensured that the analytic work could be focused. A variety of innovative attributes for measuring progress along the issues were identified and accepted.

The second step in the open planning process – scenario development – involved much more work on the part of the analysis team. Because of constraints on the advisory group's time, the analysts had to propose a variety of scenario sets for their approval and prioritization. This worked well, with the advisory group ensuring that an adequate set of options was modeled in a credible way. For example, this included rejecting demand-side options that were implausibly modeled, reviewing interim results, and appointing subcommittees to explore particular issues.

The data base development effort involved input from technical personnel in most of the organizations represented on the advisory group. The computer modeling of thousands of scenarios was time consuming but feasible, because the analysts partially automated the procedures.

The third step in the planning framework – exploring system behavior – involved mining the large data set generated during the scenario analysis. A variety of applied statistical tools were used to observe the effects of uncertainty, the performance of strategies, and the behavior of the electric power system as a whole. There was a tension between the need to amass rigorous statistical evidence of trends, and the need to communicate these trends to the busy decision makers in the advisory group. The analysis team resolved that tension by selecting a few interesting and documentable "stories" to tell to the advisory group. This reintroduced the opportunity for normative bias on the part of the analysts in choosing which of many possible "stories" to tell. However, none of the advisory group members objected, and in any case the data set was available to be examined at will by any interested party. Graphical techniques were especially useful in communicating the technical results to the advisory group.

The fourth step in the open planning framework – understanding participants' preferences – involved sorting through the strategies using increasingly normative decision rules, eliciting stakeholder values, and undertaking conflict analysis. Finding that the same decision set of strategies was robust across many different dominance criteria increased our confidence in the results. Eliciting stakeholder values and conducting a conflict assessment on them was less valuable – it merely confirmed the existence of obvious areas of conflict.

The New England project participants did not attempt the fifth step in the open planning process – seeking consensus – because they wanted to continue inventing better strategies. There was some evidence of convergence in the different stakeholders' views on good options, and they felt that further exploration would be quite fruitful.

After being presented with the technical "stories" shown in Chapter Six at the February, 1990 advisory group meeting, the participants felt that the results should be shared with a wider audience. They believed that the results to date would provoke creative discussion in the region. They asked the analysis team to go on the road, and seek feedback from other groups on: (1) the technical credibility of the results, and (2) new ideas to study in the next scenario set. Thus, instead of immediately analyzing another scenario set based on input from the advisory group alone, the analysis team expanded the level of public participation in this joint fact-finding effort to include a wide variety of groups.

Table 7-13: Presentations of the February 1990 Scenario Results from the New England Project (excluding talks to MIT and Harvard audiences)

Date		Group(s)	Attendance*
Feb	7	New England Project Advisory Group	10
Feb	20	Conservation Law Foundation	2
Mar	1	New England Electric	14
Mar	2	Commonwealth Electric	5
Mar	9	Northeast Utilities	7
Mar	9	NEPLAN	2
Mar	16	Central Maine Power	15
Mar	20	Globe '90	Conf.
Mar	24	Internat. Assoc. Impact Assessment	Conf.
Mar	21	New Brunswick Power	1
Mar	22	NESCAUM, Mass. DEP, EPA	4
Mar	27	Energy & the Envir. in 21st Century	Conf.
Apr	12	New England Environmental Exposition	Conf.
Apr	13	Maine Public Utilities Commission	15
Apr	19	NEPOOL Policy Planning Committee	15
May	16	New England Cogenerators Association	1
May	18	N.E. Governors' Conference, Power Planning Committee	32
June	6	New England Council, Energy Committee	20
June	14	Evolving Northeast Gas Markets	Conf.

* – Conf. = conference presentation, all other attendances are approximate

The first groups contacted were the organizations represented by the advisory group members. These decision makers' technical staffs were shown the results, provided with background packets summarizing the modeling assumptions, and asked for feedback. Other groups expressing an interest in the results also received visits. In addition, members of the analysis team presented the results at several conferences. In all, the analysts interacted directly with several hundred people having some level of interest in the New England electric power planning debate. The presentations are listed in Table 7-13.

These groups offered a variety of suggestions and impressions concerning the results. The input was divided into four categories: general comments, new issues, new uncertainties, and new options. They are summarized in Tables 7-14, 7-15, 7-16, and 7-17. Groups not offering comments in a particular category were not listed.

The general comments made by the groups helped the analysis team figure out how to make the next round of modeling more credible. For example, more accurate modeling of the price elasticity of electricity demand was suggested by a number of parties; the modeling framework was revised to accommodate that feedback loop.

The general comments also guided the analysts in making better presentations of technical information to non-technical audiences. For example, the use of box-and-whisker plots in presentations was largely abandoned following several basic questions about them. Instead, the use of graphs showing multiple futures (best, worst, average) were used to convey information about the consistency of results under uncertainty.

Many of the new issues raised by the groups were second order concerns relating to the strategies modeled. For example, given that repowering was a dominant strategy, what were its site and rate impacts? Similarly, given that natural gas was used in much of the new capacity, was there an adequate supply, would utility use affect residential customers, and was it too high quality a fuel to be burned in utility boilers?

Table 7-14: General Comments Made by the Groups

Conservation Law Foundation

- Back out group's tradeoff consensus on cost/ton of carbon dioxide emissions as a revealed preference.
- Study fuel price supply/demand interactions.
- Get better numbers for demand-side management technical potential.

New England Electric System

- Update assumptions used.
- Why do O.P. 4 Hours (attribute indicating reliability problems) go up with economic growth?
- Oil#2 price may track natural gas prices in long term, not vice versa.

Commonwealth Electric

- What is a box-and-whisker plot?

Northeast Utilities

- Show the fuel use by supply option in the presentation.

NEPLAN

- Normalize load growth trajectories by GRP to make them comparable.
- Distinguish between preference assumptions and those based on exp.
- Add feedback loop incorporating electric price elasticity of demand.
- Use bar charts instead of pie charts for communication.

Central Maine Power

- How much effort would be required to do this type of analysis at CMP?

Energy & the Environment in the 21st Century Conference, MIT

- Add feedback loop incorporating electric price elasticity of demand.
- Scatter plots were hard to understand.

New England Environmental Exposition, Boston

- Does repowering strategy knock independent power producers out of the future supply picture?

Maine Public Utilities Commission

- Not all utilities do least cost planning like in Massachusetts – in Maine the process is more negotiated than mechanistic.
- The range of load growths evaluated should be wider.
- What is a box-and-whisker plot?
- Demonstrate the consistency of options' performance across futures.

N.E. Governors' Conference, Power Planning Committee

- Add feedback loop incorporating electric price elasticity of demand.

New England Council, Energy Committee

- Why were no probabilities or optimal answers given?
- May we include your conclusions in our 1990 policy document?
- How were power purchases modeled?
- Call supply option set '0' Dual-Fueled instead of Gas-Dependent.

Table 7-15: New Issues Raised by the Groups

New England Electric System
- Evaluate transmission-related site impacts.
- Model major discontinuities instead of monotonic trends.
- Evaluate site impacts of repowering.
- Measure the solid wastes from AFBC (new coal) plants.
- Consider the "moral value" of high quality fuels like natural gas.
- Will increased electric utility gas consumption increase residential gas prices?

Northeast Utilities
- Evaluate rate shock for different strategies.
- Evaluate intra-regional equity regarding emissions.

Globe '90 Conference
- Does New England have enough natural gas to supply power plant needs?

New Brunswick Power
- Clean coal plants in New Brunswick need scrubbers for public relations purposes, even though AFBC and IGCC technologies have minimal sulfur dioxide emissions.

New England Environmental Exposition
- Evaluate rate shock from repowering strategy.
- Does New England have enough natural gas to supply power plant needs?

Maine Public Utilities Commission
- Evaluate transmission-related site impacts.
- Does New England have enough natural gas to supply power plant needs?

NEPOOL Policy Planning Committee
- Evaluate intra-regional equity regarding emissions, site impacts, generation and transmission impacts of the strategies.
- Evaluate Canadian site impacts of power purchases strategies, including flooding and drowned-tree CO_2 emissions.
- Evaluate utility demand-side programs peak-to-energy savings ratios.
- Evaluate rate shock for different strategies.
- Distinguish between costs and rates.
- Distinguish between utility demand-side program participants and non-participants when measuring rates.

New England Cogenerators Association
- Elicit regulators' intentions regarding the creation of an independent power producers' market.

Table 7-16: New Uncertainties Suggested by the Groups

New England Project Advisory Group
- Explore a wider range of fuel price uncertainties.

New England Electric System
- Add optimistic vs. pessimistic power purchases availability.
- Add optimistic DSM interactions case to make that uncertainty symmetric.

NEPOOL Policy Planning Committee
- Explore fuel prices.
- Explore natural gas availability.
- Explore sporadic construction delays.

New England Cogenerators Association
- Explore natural gas availability.

N.E. Governors' Conference, Power Planning Committee
- Explore natural gas availability.
- Explore wider range of uncertainty in capital costs, on both demand- and supply-side investments.

The uncertainties mentioned by the groups also related to the strategies they were shown. For example, natural gas availability worried people, as did a wide variety of fuel prices. Concern about capital costs and construction delays also surfaced, as the dominance of certain supply options in the current data set became apparent.

The new options suggested by the groups also built upon the existing set. There was a great deal of interest in refining the options that targeted the environmental and reliability problems of existing capacity. Non-fossil options such as solar and nuclear also attracted interest. The concept of using an environmental (instead of economic) dispatch logic in operating the region's power plants also gained a great deal of interest, as the environmental effects of existing capacity became better understood. Obvious options that were missing from the current data set – such as coal – also caught peoples' attention.

Table 7-17: New Options Suggested by the Groups

New England Project Advisory Group
- Clean coal (AFBC and IGCC technologies).
- Photovoltaics.
- Options targeting the problems of existing capacity.

Conservation Law Foundation
- Stronger DSM programs, esp. conservation-oriented load shapes.
- Low sulfur oil (#2 and #6) for existing and new capacity.
- Replacement of old power plants (forced retirement).
- Additional new power plants (based on environ. not reliability targets).
- Electricity-to-gas residential end-use switching.
- Coal strategies.

New England Electric System
- Non-fossil power purchases.
- Coal strategies.
- Low sulfur oil#6 for existing plants.
- Reliability-targeted strategies.
- Environmental dispatch.

Commonwealth Electric
- Clean coal (IGCC technology).

Northeast Utilities
- Nuclear.
- Environmental dispatch.

NEPLAN
- Scrubbers on new and existing capacity.
- Solar (esp. photovoltaics).
- Nuclear.
- Targeted demand-side management.
- Environmental dispatch.

NESCAUM, Mass. DEP, US EPA
- Replacement of old plants (forced retirement).

Energy & the Environment in the 21st Century Conference
- Replacement of old plants (forced retirement).

Maine Public Utilities Commission
- Interruptible rates as a major option instead of a small fixed feature.
- Environmental dispatch.

NEPOOL Policy Planning Committee
- Coal.
- Nuclear.

New England Cogenerators Association
- Alternative fuel choices (gas, low sulfur oil).

N.E. Governors' Conference, Power Planning Committee
- Coal.

New England Council, Energy Committee
- Alternative fuel choices (gas, low sulfur oil).

Evolving Northeast Gas Markets Conference
- Alternative fuel choices (gas).

The responses of both the New England project advisory group and the many other parties with which the results were shared suggest that this effort is indeed improving the quality of the public debate. Better options are gaining attention as a result of this work. The debate is also moving off of single option solutions towards multi-faceted strategies for ensuring adequate electric service in the region.

One indicator of progress is the quality of the debate surrounding the Massachusetts Department of Public Utilities proposed rulemaking 86-36-FG/89-239 (1988-1990). This ongoing enquiry into the best way to ensure that utilities engage in integrated resource planning has provided a forum for expressing ideas about power planning in general. In 1989, much of the focus was on technology-specific characteristics of new planning options – measuring their environmental impacts in isolation, for example. By 1990, a number of commenters emphasized the need to consider existing capacity in the planning process, and the need to consider system-wide rather than unit-specific environmental impacts. The 1990 draft regulation included a pre-filing consensus-building step, and recognized the need to optimize the utility's portfolio of projects in a step that was distinct from the mechanistic bidding process. Based on this indicator, the quality of the public debate is being improved.

As of this writing, the New England project is ongoing, and another set of scenarios is being run based on input from the many groups listed above. The project (to date) has been a success at joint factfinding, spurring the inventiveness of its participants, and improving the quality of the regional power planning debate. It has helped to make progress towards a consensus, but it is not clear whether it is a suitable forum for formal consensus decision making. Individual decision makers may prefer to take the information gained back to own domains and use it to make better independent decisions. While individual stakeholders continue to disagree about the relative importance of attributes such as cost and environmental impacts, they are finding common ground in a number of areas. The debate has progressed to the point of defining multi-faceted strategies instead of polarized single-option solutions. The paralysis in this planning process is being overcome.

8. USING THIS APPROACH WITH NON-EXPERT GROUPS: THE COM/ELECTRIC OPEN PLANNING PROJECT

This chapter discusses a second electric power industry application of the open planning approach and scenario-based multi-attribute tradeoff analysis framework. This case differed from the New England project described in previous chapters in two significant ways: its scope was utility-specific instead of region-wide, and it targeted lay instead of expert audiences.

Background

On December 8, 1988, one of the officers of the Commonwealth Electric Company (COM/Electric) attended our presentation to the NEPOOL Policy Planning Committee of the first round of regional tradeoff analysis. The following month, that officer (Vice President, Resource Planning and Development) asked the MIT Energy Lab to help develop a similar analytic capability at COM/Electric.

This request was motivated by several things. First, COM/Electric had been ordered by the Massachusetts Energy Facilities Siting Council (EFSC Decision No. 86-4) to improve its resource planning method so that (among other things) it would in the future: (1) include demand-side programs using a "level playing field;" (2) plan more thoroughly for contingencies; (3) compare a larger range of generation and non-generation alternatives; and (4) model supply plans in a more plausible manner.

Second, the Massachusetts Department of Public Utilities had issued an Order (DPU 86-36-F) on November 30, 1988 that paved the way towards requiring utilities to use an "all resource solicitation" process within an "integrated resource management" framework, for future resource plans (see discussion of this order in Chapter Five). Major implications of this order included the need to account for environmental externalities in the planning process, and to better integrate demand-side and supply-side planning. The Department was casting around for ideas about the best way to include something as subjective as environmental externality evaluation in a rigorous, reviewable planning framework.

The third factor influencing COM/Electric's request was personal: unlike most of the company's officers, who preferred to remain invisible behind a corporate veil, this vice president was a regular actor in local politics. He had learned to value public participation in planning processes for its public relations benefits and the increased credibility with regulators that it provided the company. He also believed more openness to be desirable in and of itself.

In January 1989 COM/Electric contracted with MIT to provide "integrated resource planning assistance" in order to "enhance their planning processes and develop a framework for useful public discussion of utility planning issues" (AGREA, 1989e). Specific tasks included reviewing current planning methods, expanding the company's ability to function in open planning processes, developing their multi-attribute tradeoff analysis capabilities, performing public education on utility planning issues, and exploring issues relating to the interactions between the utility and the region. The formation of an advisory group structure similar to that used for the New England project was envisioned, to discuss issues and options, develop scenarios for evaluation, and review the results and implications of ongoing analyses.

On February 1st, 1989, MIT made two presentations at COM/Electric, one to the senior management and the customer service department, and the other to the planning department. The story of the New England project was used to illustrate the motivations, methods, and results of open planning with an advisory group, using a scenario-based multi-attribute tradeoff analysis framework. An "internal advisory group" was appointed following these meetings to serve as a sounding board for the analysts while modeling tools were developed, and to allow the participants to have a dry run of the whole process with a "safe" audience. The COM/Electric planning department and the MIT participants became the project's analysis team.

During the spring of 1989, the analysis team carried out its review of COM/Electric's current planning methods, and determined which of their existing computer models were useful for different components of multi-attribute analysis. The team also developed a strategy for integrating these packages together to allow multiple scenarios to be expeditiously run. They began writing the computer code to interlink the various models and thereby partially automate the analysis tools (see Appendix C2 for details). Linking the main production simulation model together with other parts of the scenario analysis engine turned out to be more difficult than in the New England project.

The New England simulator was designed to operate in batch mode, using old fashioned (but easily manipulable) fixed address 80 character card-width formatting. This made controlled experiments, or scenario analysis involving changes in only one input parameter at a time, relatively easy to automate into large batch jobs. The COM/Electric simulator, on the other hand, was designed for interactive use. Its input section was user-friendly, flexible, and text oriented, allowing word-processing-like cutting and pasting of input blocks into long, repetitive, if easy-to-understand files. This flexible format was much harder to automate, because the entire input block had to be recreated each time a single parameter changed. The voluminous character of both the input and output files made large batch jobs difficult on a memory-constrained machine. The mode of operation was to run smaller batch jobs, followed by data reduction and deletion of input files before running the next batch.

On June 27th, 1989, the first internal advisory group meeting was held. The six participants, representing different parts of the company, discussed the range of issues, attributes, uncertainties, and options that would most likely be of interest to an external advisory group (and were definitely of interest to COM/Electric). Afterwards they filled out questionnaires prioritizing various issues, attributes, uncertainties, options, and strategies for the purpose of scoping the study. This led to a general focus on the cost, reliability, and environmental impacts of electric service.

A month later, the second internal advisory group meeting was held to specify the scenario set. An important part of this meeting was reviewing the technical details of the options and uncertainties that were to be modeled, checking both their accuracy and completeness. Meanwhile, the painstaking work of creating an integrated modeling system went forward. The MIT group took the lead on this portion of the work, while the COM/Electric planning staff provided information for the modeling effort as requested.

Coordination of the open planning project with COM/Electric's existing planning activities took place concurrently with the computer programming work. For example, during October 1989, the COM/Electric demand-side planners traded ideas with the MIT team about how to incorporate environmental externalities into the cost-benefit calculations by which demand- and supply-side resources were screened. At a meeting on November 2nd, 1989, these parties established that scenario-based multi-attribute tradeoff analysis should be used at the beginning of the planning process to identify strategies that were efficient (along multiple attributes) and robust under uncertainty. The open planning process, through advisory group interactions, would provide guidance in weighting attributes and ranking strategies. Based on the advisory groups' revealed preferences, COM/Electric would then select a strategy (i.e., a specific portfolio of options) to pursue. They would request third party bids to implement specific options, rank the proposals, test to see that the actual projects in the award group formed a similarly attractive portfolio as its generic precursor (considering multiple attributes and uncertainty), and sign contracts.

The existing planning process depended heavily on two concepts that were somewhat at odds with the multi-attribute tradeoff analysis approach. The first was its dependence on avoided costs of supply as the benchmark for screening demand-side programs. The avoided cost concept became meaningless when a wide range of supply options rather than a single base case was considered, because that led to a wide range of avoided costs of supply. Further, a static avoided cost measure would not capture the interactive, or "portfolio" effects of coordinated strategies consisting of supply *and* demand-side options. It therefore became a goal of the new integrated resource management process at COM/Electric to evaluate resources based on "least social cost" of a coordinated strategy rather than avoided costs of specific supply options. Avoided costs (based hereafter on the most recent award group) would be used only for the initial screening of individual demand-side options in the future, not for final resource selection.

The second part of the existing planning process that was at odds with the new approach was the need to develop environmental externality "adders" to serve as shadow prices for non-market costs in the cost-benefit analysis of planning options. Environmental adders of some type, either in points or in dollars, were a regulatory requirement in the planning process as of November 30, 1988 (MA DPU 1988). In the multi-attribute tradeoff analysis approach, the environmental impacts were measured directly, and the marginal rate of substitution between cost and environmental attributes (i.e., the shadow price) was considered highly context-specific. It depended not only on the preferences of the particular parties evaluating these tradeoffs, but also on the particular set of strategies on the table. Thus it was not clear that there should be general use of the shadow prices revealed by the preferences of the advisory group members. However, since the decision making process in the open planning approach (of which these shadow prices would be a residual) appeared sound, COM/Electric presumed that context-specific environmental adders could be applied *ex post* to document the outcome of the planning process for the regulators.

A subsequent ruling (MA DPU 1989) clouded this issue by specifying that environmental adders would be uniformly imposed statewide, thus weakening the justification for context-specific shadow prices. However, the Department of Public Utilities did not specify the magnitudes of these adders, and instead asked for public input in setting their levels. The COM/Electric open planning project therefore went forward with the added goal of testing public perceptions of the proper shadow prices to apply.

Organizing the Advisory Groups

On November 7th, 1989, COM/Electric, MIT, and a public relations firm met to organize the logistics of the external advisory groups. For this initial experiment, it was decided that there should be four advisory groups, one for each of the company's service districts: Cambridge, Plymouth, New Bedford, and Cape Cod. Each group would have three meetings of about two hours in length, about three weeks apart, facilitated by a member of the MIT team. The goal was to have about a dozen regular participants in each advisory group. The public relations firm began developing letters of invitation, while COM/Electric's district service representatives identified a "cross section of leading citizens" who should participate.

The next internal advisory group meeting was on November 20th, 1989. The focus of that meeting was on an initial set of results: eighteen scenarios exploring one supply option set, three demand-side option sets, three load growth uncertainty values, and two fuel price uncertainty values. The meeting had two goals, first, to check the credibility of the results, and second, to discuss techniques for communicating technical information to non-technical audiences.

Following minor technical comments by COM/Electric personnel, the public relations experts made suggestions about ways to get MIT's technical message across to a lay audience. They stressed that the meetings must be enjoyable to the participants, and recommended using a pre-packaged video or slide show so that interruptions would not dilute the message. They warned that the audience was likely to be intimidated by the MIT speaker, and that the initial presentation should therefore use non-technical language, and be as accessible as possible.

The detailed objectives of the three external advisory group sessions were spelled out in a meeting with the vice president in charge of the project at COM/Electric on January 5th, 1990. They were as shown in Table 8-1.

Table 8-1: Agendas

SESSION 1

- Introductions
- Describe Open Planning Concept
- Explain COM/Electric's Desires for Open Planning
- Outline Known Issues of Importance
- Discuss Base Resource Plan and Alternatives
- Identify Major Uncertainties
- Elicit Consumer Issues and Concerns
- Outline Work to be done for Session 2

SESSION 2

- Present Composite Results of Outlined Work
- Identify Trade-offs
- Revisit Issues and Concerns
- Outline Additional Work for Session 3 to Develop Composite Plan

SESSION 3

- Present Composite Plan
- Seek Areas of Consensus
- Evaluate Project

The initial sessions were to be prefaced by a mailing providing this agenda, a note on overall goals, and newspaper clippings containing background information. It was agreed to develop a slide show for the first meetings, to cover basic background information on COM/Electric, the concepts and vocabulary of the open planning process, and examples of the types of tradeoffs to be confronted in subsequent meetings. The remainder of the first meetings would be interactive, with a facilitator eliciting issues, uncertainties, and possible options from the groups, and then prioritizing the issues. The remaining meetings would rely on viewgraphs instead of slides to convey information because of the quick turn-around time required, with only three weeks between meetings during which to conduct analysis.

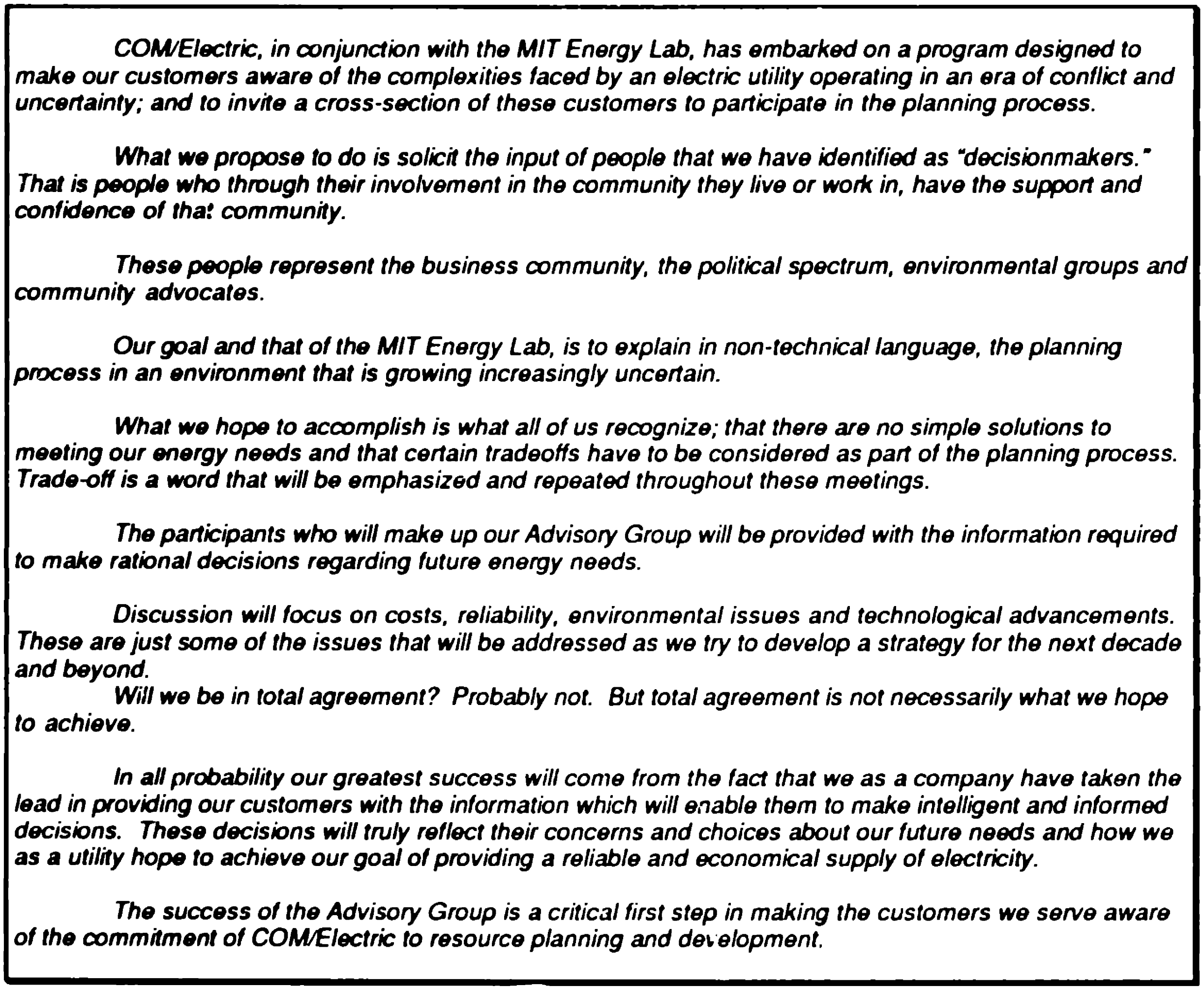
From a planning perspective, the points that COM/Electric hoped to get across in the external advisory group sessions included the: (1) company's desire to open up its planning process; (2) company's obligation to serve all of customers' loads; (3) characteristics of the available options; (4) existence of multiple decision criteria: economics, environment, level of service; (5) need for the company to make tradeoffs among criteria when choosing options; and (6) company's desire to understand customers' preferences regarding the tradeoffs.

Related factors looming on COM/Electric's horizon included a new resource plan to be filed with the Energy Facilities Siting Council and the Department of Public Utilities, the need to develop a sound environmental externality evaluation approach, and a switch to all resource bidding for new increments of capacity.

On February 2nd, 1990, MIT presented a dry run of the slide show to the COM/Electric internal advisory group, based on the results of 108 scenarios calculated to date. These were then turned into finished slides. A month later MIT presented a detailed technical exposition of these results to the internal advisory group; giving them their last chance to catch technical errors. The following week the first external advisory group sessions began.

The citizens that COM/Electric invited to the meetings came from a variety of backgrounds (see participants' list in Appendix D). Their letters of invitation included the overview of the open planning project shown in Figure 8-1.

Figure 8-1: Overview of the COM/Electric Open Planning Project
Source: COM/Electric 1990



COM/Electric, in conjunction with the MIT Energy Lab, has embarked on a program designed to make our customers aware of the complexities faced by an electric utility operating in an era of conflict and uncertainty; and to invite a cross-section of these customers to participate in the planning process.

What we propose to do is solicit the input of people that we have identified as "decisionmakers." That is people who through their involvement in the community they live or work in, have the support and confidence of that community.

These people represent the business community, the political spectrum, environmental groups and community advocates.

Our goal and that of the MIT Energy Lab, is to explain in non-technical language, the planning process in an environment that is growing increasingly uncertain.

What we hope to accomplish is what all of us recognize; that there are no simple solutions to meeting our energy needs and that certain tradeoffs have to be considered as part of the planning process. Trade-off is a word that will be emphasized and repeated throughout these meetings.

The participants who will make up our Advisory Group will be provided with the information required to make rational decisions regarding future energy needs.

Discussion will focus on costs, reliability, environmental issues and technological advancements. These are just some of the issues that will be addressed as we try to develop a strategy for the next decade and beyond.

Will we be in total agreement? Probably not. But total agreement is not necessarily what we hope to achieve.

In all probability our greatest success will come from the fact that we as a company have taken the lead in providing our customers with the information which will enable them to make intelligent and informed decisions. These decisions will truly reflect their concerns and choices about our future needs and how we as a utility hope to achieve our goal of providing a reliable and economical supply of electricity.

The success of the Advisory Group is a critical first step in making the customers we serve aware of the commitment of COM/Electric to resource planning and development.

First Meetings: Introduction, Prioritizing Issues, and Brainstorming for Options

Although the schedule, presentation, and meeting organization were similar for the four advisory groups, each of them quickly evolved in a unique direction. This could be seen in the attendance, issues raised, pattern of discussion, and final outcome. The population of the COM/Electric service territory was clearly not homogeneous, even for the small and non-random sample participating in this experiment (see participants' list in Appendix D).

In Cambridge, eight of the ten citizens who had accepted invitations attended the first meeting on March 5th, 1990. These included a state representative, and spokespeople for the City of Cambridge, neighborhood associations, major industries and institutions, Chamber of Commerce, and anti-development interests. All of the attendees were active in the discussion, but three were especially vocal – out of a total of 36 comments made, they each made seven or more, compared to an average of 4.5. These three represented Polaroid, the City of Cambridge, and the Hastings Square Neighborhood Association. The highest priority issue for the group was environmental impacts, with electricity cost and reliability tied for second place, based on a show of hands in which each participant was allowed two votes. See Tables 8-3, 8-4, and 8-5 for a complete list of issues, uncertainties, and options generated at the meetings.

The Plymouth meeting, held on March 6th, 1990, the evening of the year's worst snowstorm, had low attendance, with only four attending out of the eleven who had accepted invitations. These four included the state representative, a representative of the Board of Selectmen, president of the local newspaper chain, and president of a local bank. Again, all of the attendees were active in the discussion, although one person (from the Board of Selectmen) was particularly vocal. This person provided ten of the 27 comments, compared to an average of 6.75. Reliability was the only issue that garnered more than a single vote (out of 2x4=8 possible). Environment, cost, energy education, and the value of commercial demand-side management subsidies each received one vote.

New Bedford enjoyed a higher turnout than expected at its meeting on March 8th, 1990. Although only six people had accepted invitations, ten showed up. These included representatives of the mayor's office, other nearby municipal governments, local industry, local newspapers and television, the United Way, the county development council, and a cranberry grower. Participation in the discussion was much more uneven, with individuals contributing from zero to seven comments each, for a total of 31 comments. The most vocal person was the president of a local industry (whose electricity costs had recently increased), all of whose comments were about different aspects of electricity cost: its average level, volatility, rate structures, the resulting competitive position of the region, and the corporate productivity or operating efficiency of COM/Electric. Not surprisingly, the highest priority issue in the voting was electricity cost, followed by environmental impacts. The credibility and operating efficiency of the utility tied for a distant third place.

The first meeting in Cape Cod was on March 14th, 1990. Seven of the ten people who had accepted invitations showed up. They included a state senator and his aide, and representatives of the regional planning and development commission, a hospital, a bank, a retail chain, and the Chamber of Commerce. This group enjoyed the most active discussion among the four initial sessions, making 51 comments, an average of 7.3 per person. Three participants were especially vocal: the retailer made fifteen comments, many revolving around adequacy of supply; the state senator made eleven, covering a range of company credibility, public health, and policy issues; and the planning commission staffer made nine, focusing on environmental impacts and innovative technical options. The group had a thorough discussion of the various levels of environmental impacts – local, regional, and global – and their different types – æsthetic impacts on sites, emissions, waste disposal, electromagnetic fields, land and water use – as well as expressing concern for the uncertainties, such as threshold effects, associated with many impacts. In voting, they ranked environmental issues as their highest priority, with reliability and Company communications efforts equally sharing the remaining votes. Unlike the other groups, cost issues received no votes on the Cape.

All of the meetings were organized in a similar manner, beginning with a slide show (see Table 8-2 for the script). The slides served to introduce the participants to the project, COM/Electric, and the open planning process. It also discussed the desired results, and provided examples of options, impacts, and uncertainties. It closed with a request for input from the group. Using a blackboard, the facilitator led the group in brainstorming electric power-related issues of concern to them, then uncertainties that affected these issues, and finally options that COM/Electric could bring to bear over the next twenty years to address the issues. After the brainstorming session, the facilitator went back and asked the group to prioritize the issues by voting for their favorites. Uncertainties and options were not prioritized.

Table 8-2: Slideshow Script for 1st COM/Electric Sessions
Source: AGREA 1990c

Segment	*Slide No.*	*Title/Contents*	*Point/Bridge*
Intro to Project and Participants	1	The Open Planning Process/Boardroom	
	2	COM/Elec—MIT Logos	MIT Analysis-COM/Elec Initiative
	3	COM/Elec Service Territories & Companies	Dealing w/ Complex Systems
Intro to Open Planning Process	4	The Open Planning Process/Plain	Need to Address the Complexity
	5	Components-Issues	
	6	Components-Uncertainties	
	7	Components-Options	
	8	Components-All Together	
	9	Issues	Goals/Concerns
	10	Issues-Cost of Electricity	
	11	Issues-Environmental Impacts	
	12	Issues-Reliability, etc.	
	13	Uncertainties	Constraints/Concerns
	14	Uncertainties-Fuel Prices	
	15	Uncertainties-Load Growth	
	16	Uncertainties-many others...	
	17	Options	
	18	Options-DSM	
	19	Options-Supply-Side	
	20	Options-Both/Strategies	How to Implement?
	21	Analysis Process	Many, Many Scenarios
	22	Issues-All	How to Measure?
	23	Cost of Electricity-Measures	
	24	Environmental Impacts-Measures	
	25	Reliability-Measures	
Results from Such a Process	26	What are the Trade-Offs?/Boardroom	What kind of results do we get?
	27	Three Sample Classes-Cost/Environ./Uncer.	Need to review set of Options
What are the options?	28	DSM Programs	Lots of other options viewed...
	29	Current Programs	Actual
	30	Additional Programs	Feasible
	31	No Programs	Comparative
	32	Theoretical Maximum	Hypothetical/Comparative
	33	Three Sample Classes-Encore	
Cost Impacts	34	Cost Impacts	
	35	DSM Investment Up/Total Costs Down	
	36	Unit Costs Up/Total Use Down	
	37	Monthly Bill Down	...but only if you Conserve
Environmental Impacts	38	Environmental Impacts	
	39	Fewer Plant Sites-Bullet	
	40	Fewer Plant Sites-Graph	
	41	Mixed Emissions-Bullet	
	42	CO2 Down-Bullet	
	43	SO2 Can Increase Bullet	
	44	CO2 & SO2 Graph	DSM doesn't pollute...
	45	Why Don't Emissions Decrease-Graphic	but deters Supply-Side efficiency
	46	CO2 & SO2 Graph	DSM doesn't pollute...
Effects of Uncertainties	47	Effects of Uncertainties	Driven by Fuel Price Forecast
	48	Load Growth-Incr. Nat.Gas/Efficiency/Env.Q	and Relative Fuel Prices
Planning for the Future	49	Planning for the Future	
	50	Requires your input	
	51	Prioritize Issues/Concerns	
	52	Develop Strategies	
	53	End-Issues/Uncertainites/Options ???	Open up discussions...

After the initial round of advisory group meetings was finished, the analysis team aggregated the results to guide them in preparing for the next meetings. Issues and uncertainties were divided into those that could be analyzed in detail, and others for which the team could only summarize existing research. Across all meetings, many of the same issues surfaced without prompting from the facilitator, but they were often accorded different priorities. As Table 8-3 shows, issues that were highly-ranked in most of the groups included environmental impacts, electricity costs, and reliability of supply. These formed the basis for the analytic work. For other issues, such as regional competitiveness and the health effects of electromagnetic fields (EMF), an information package containing short summaries and excerpts of articles was prepared. The high priority issues guided the choice of attributes to be modeled.

Many of the same uncertainties surfaced in each of the four meetings (see Table 8-4). Based on the aggregated input from the groups, the analysis team modeled the following uncertainties in detail: economic and electricity load growth, fuel prices and availability, customer response to utility conservation measures, and escalating capital costs. Likewise, a limited set of options were repeatedly suggested (see Table 8-5). The analysis team fashioned these into a variety of strategies and modeled them.

Using the integrated modeling setup that had been developed over the previous year, and the information on options and uncertainties that had been explored to date, the analysis team was able to quickly model strategies reflecting the aggregate interests and concerns of the four advisory groups. During the one month between the first and second sets of meetings, the group defined the new scenario set, acquired data needed for accurate modeling, and ran the first 48 scenarios.

Table 8-3: Issues

Results of discussions with COM/Electric Consumer Advisory Groups during March 5 - 14, 1990.

Action	TOTAL	Rank Sum	CAMBRIDGE	Rank	Votes	PLYMOUTH	Rank	Votes	NEW BEDFORD	Rank	Votes	HYANNIS	Rank	Votes
Analyze	**Environment**	6	**Environment**	1	5	**Environment**	2	1	**Environment** Atmospheric Emissions Siting of Cogenerators	2	7	**Environment** Atmospheric Emissions Visual impacts Nuclear Waste Disp.	1	6
Analyze	**Cost**	8	**Cost** Predictability of costs Welfare/Lifeline Rate Cross-subsidies Equity Impacts of DSM	2	3	**Cost**	2	1	**Cost** Utility as Social Welfare Organization	1	9	**Cost**	3	0
Analyze	**Reliability**	9	**Reliability** Long-term Adequacy of Supply Viability	2	3	**Reliability**	1	2	**Reliability**	4	0	**Reliability** Adequacy of Supply	2	4
Summarize	**Communications**	11	**Communications**	4	0	**Communications** Education	2	1	**Communications** Credibility of Utility	3	2	**Communications** Accountability Image/Credibility Govt. Energy Policy	2	4
Summarize	**Regional Competitiveness**	13	**Regional Competitiveness** Jobs	3	1	**Regional Competitiveness**	3	0	**Regional Competitiveness** Jobs	4	0	**Regional Competitiveness**	3	0
Summarize	**EMF/ Transmission**	14	**EMF/ Transmission**	4	0	**EMF/ Transmission** Transm. & Distr.	3	0	**EMF/ Transmission**	4	0	**EMF/ Transmission** Technology-Related Mystery	3	0
Move to Uncertainty or Options List			Others Local Capacity Implications of Large Comm. Projects Security of supply	3 3	1 1	Others HVAC Subsidies and Building Codes	2	1	Others Increased Efficiency of Supply/Operation	3	2	Others		

Table 8-4: Uncertainties

Results of discussions with COM/Electric Consumer Advisory Groups during March 5 - 14, 1990.

Action	COMBINED	CAMBRIDGE	PLYMOUTH	NEW BEDFORD	HYANNIS
Analyze	Fuel Price	Fuel Price	Fuel Price	Fuel Price	Fuel Price
Analyze	Fuel availability	Fuel availability	Fuel availability esp. of foreign supply and gas	Fuel availability Availability of alternative resources	Fuel availability
Analyze	Technological developments (timing,availability, performance, costs)	Technological developments	Technological developments Adequacy of R&D	Tech. availability Adequacy of R&D	Technological developments new techs
Analyze or Summarize	Regulation	Regulation Legislation Gov't funding of tax credits incentives, etc.	Regulation	Regulatory behavior r.e. supply options (R&D) (Siting) (Rates) Restructure industry Supply Competition Deregulate wheeling	Regulation
Analyze	Load growth		Economic growth	Economic growth Load growth Plant closings New homes/condos	Economic growth Load growth Cost of doing business Lower water table Changing land-uses new loads (electric car)
Analyze	Capital requirements	Capital costs	Capital costs	Cost of implementation	Citizens' perceptions /responses to utility actions
Analyze Summarize	Cost of capital				
Analyze	Customer response to DSM			Customer awareness of problems; disbelief that problem exists	Willingness to conserve or alter lifestyles
Summarize	Other	EMF health impacts Thresholds of serious emissions impacts Seabrook & rates Potential for consensus	Environmental unknowns Fragility of Transm. losing Cape Cod Which fuels will new plants burn?	Credibility r.e. volatile el. cost Role of utility in welfare provision	health effects of el.prod. Erosion

Table 8-5: Options

Results of discussions with COM/Electric Consumer Advisory Groups during March 5 - 14, 1990.

Action	COMBINED	CAMBRIDGE	PLYMOUTH	NEW BEDFORD	CAPE COD
Analyze	**Renewables**	Renewables	PV, Wind, Local Hydro,Trash	Trashburners	Renewables
Analyze	**Conservation and Load Management**	Conservation and Load Management	Expanded Conservation and Load Management HVAC subsidies	Conservation and Load Management Innovative rates	Conservation and Load Management Innovative rates Electric Heat-Fuel Substitut'n Standards
Analyze	**Nuclear**	Nuclear	Nuclear		Nuclear
Analyze	**Clean Coal**	Clean Coal	Clean Coal	Clean Coal	Clean Coal
Analyze	**Natural Gas**	Natural Gas			Natural Gas
Analyze	**Non-Utility Generation**	NUGs/IPPs Cogeneration	Cogeneration	NUGs/IPPs Cogeneration	
Analyze	**Power Purchases**	Power Purchases	Canadian hydro	Power Purchases	Power Purchases
Summarize	**Wheeling/Access Restructuring/ Competition**	Wheeling			Wheeling
Analyze	**Repowering**	Repowering	Repowering	Repowering w/coal	Repowering
Summarize	**Others**	Scrubbers on existing plants Do nothing Diversity Location Competition	Diversity	Competition	Competition

On April 4th, 1990, a mailing was sent to the participants providing a schedule of the next meetings, a summary of issues, uncertainties, and options discussed in the initial meetings, and fact sheets about selected options. The mailing also identified the strategies that would be modeled. These included two levels of demand-side activity: current utility programs and an enhanced version of those programs. On the supply-side, gas- and oil-fired generation, clean coal technology, repowering of some existing plants, advanced-design nuclear power plants, cogeneration, and solar photovoltaics would be modeled.

Second Meetings: Interim Results, Prioritizing Attributes and Uncertainties

The second round of external advisory group meetings began in Cambridge on April 23rd, 1990. The purpose of these meetings was to review the overall concerns expressed by the four consumer advisory groups, to present to each group the issues, uncertainties, and options being included in the scenario analysis, and examine the results for a subset of the scenarios to familiarize the participants with the technical concepts.

The predominant issues identified by the four consumer advisory groups were broken down into four general areas: environmental quality, cost of electric service, reliability of electric service, and the efficiency of electric service provision. Sub-issues, and the attributes used to measure them are listed in Table 8-6.

Table 8-6: Issues and Attributes for the COM/Electric Project

Issue Sub-Issue	Attributes, or Measures
Environmental Quality	
Acid Rain	SO_2, NO_x, and Particulate Emissions
Ground Level Ozone	NO_x Emissions
Global Warming	CO_2 Emissions
Land Use	No., Size and Footprint of New Powerplants
Nuclear Waste	High Level Wastes
Cost of Electric Service	
Level of Cost	Total Cost of Electric Services
Volatility of Costs	Maximum Ann'l Increase in Cost of Service
Reliability/Adequacy of Electricity Supplies	
Frequency of Shortages	Hours in NEPOOL Emerg. Operating Levels
Natural Gas Consumption	Percent of Present Consumption
Efficiency of Electric Service Provision	
End-Use Efficiency	Percent Reduction in Peak Load
Supply-Side Efficiency	Percent Increase in Powerplant Efficiency
Total System Efficiency	Product of End-Use & Supply Reductions

The predominant uncertainties modeled for the four consumer advisory groups were broken down into three areas: economic/load growth (3 values – L, B, H), fuel prices (2 values – L, H), and customer response to demand-side management programs (3 values – L, B, H). Changes in capital costs were relegated to secondary status by the analysis team, who hoped to evaluate their effects only through sensitivity runs (thus its modeling designation was always 'B'). Figure 8-2 shows the three trajectories for economic/load growth, while Figure 8-3 shows those for low and high gas prices (all other fuels behaved the same in both cases). Customer response to DSM programs was either as expected, achieved 50% less energy savings than envisioned, or 50% more. This yielded a total of (3 x 2 x 3 = 18) 18 futures to be modeled.

Figure 8-2: Economic/Load Growth Trajectories for the COM/Electric Project
Note that they include Collaborative DSM Programs
with Expected Customer DSM Responsiveness
Source: AGREA 1990b

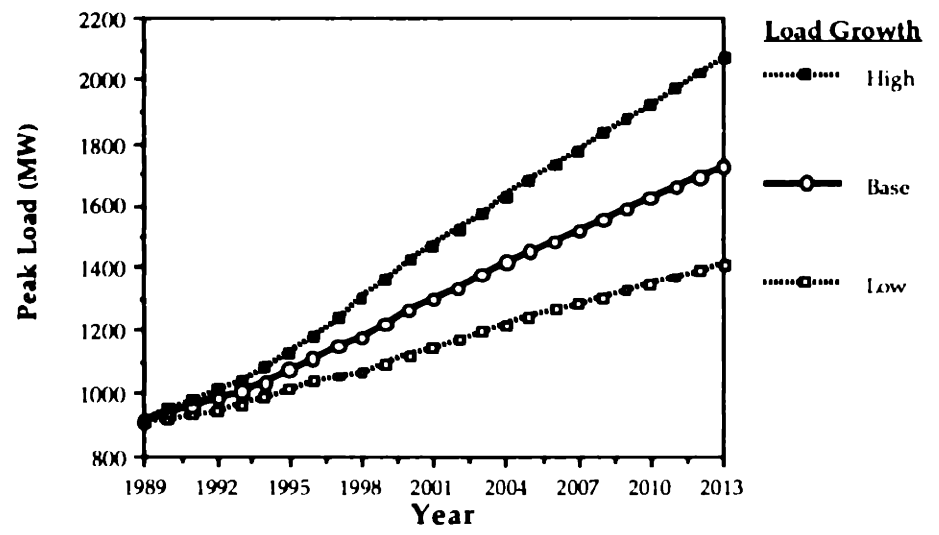
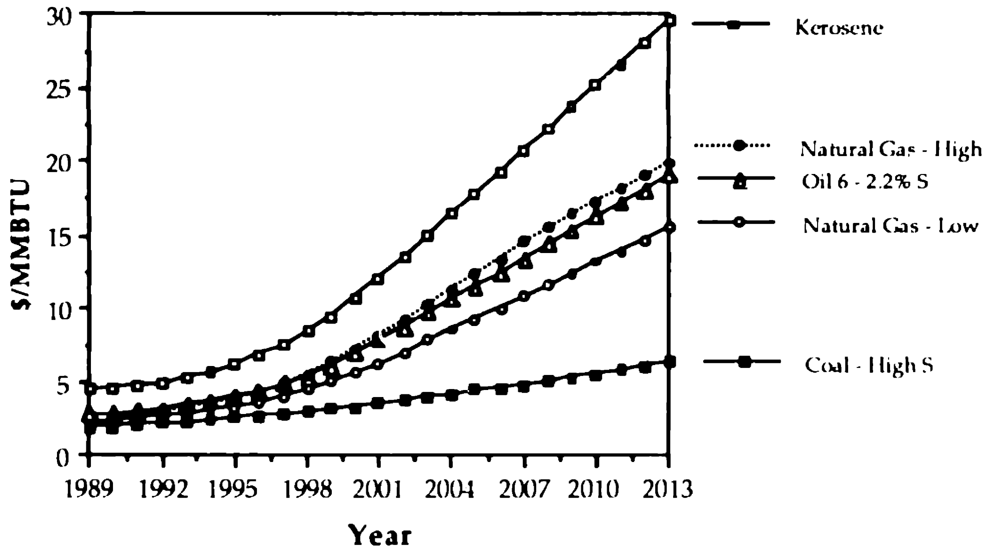


Figure 8-3: Fuel Prices for the COM/Electric Project
Source: AGREA 1990b



The strategies modeled for the COM/Electric open planning project included three components: demand-side options, supply-side options, and reliability targets. Table 8-7 defines the (2 x 10 x 2 = 40) 40 strategies. Exhaustively combining these strategies with the futures described above yielded a total of (18 x 40 = 720) 720 scenarios.

Table 8-7: Strategies for the COM/Electric Project
Source: AGREA 1990b

Strategies

Option Sets are combined into Strategies

Demand Option Sets

C — Collaborative Programs	E — Enhanced Collaborative

Supply Option Sets

Supply Option Sets	*Combined Strategies*	
A - Gas Dependent	AC	AE
B - Gas Dependent with Low Sulfur Oil	BC	BE
C - Repowering	CC	CE
D - Repowering with Low Sulfur Oil	DC	DE
E - Gas and Clean Coal	EC	EE
F - Clean Coal Dependent	FC	FE
G - Clean Coal and Repowering	GC	GE
H - Canal 3 and Gas	HC	HE
I - Nuclear	IC	IE
J - Photovoltaics	JC	JE

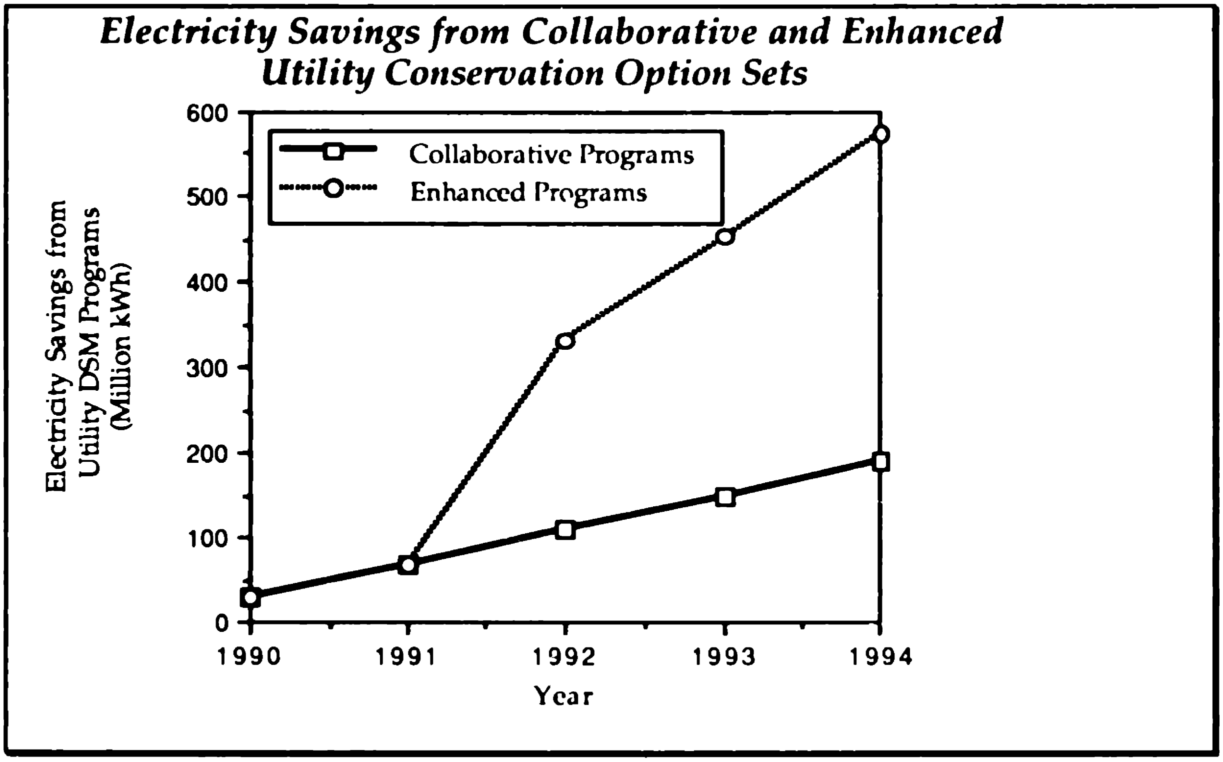
Reserve Margin Options

Each of the above strategies will be evauated under a base reserve margin of 23% (L), and a high reserve margin of 30% (H) to assess reliability impacts.

Example: Gas Dependent Strategy with Collaborative conservation programs and a High target reserve margin would have the label ACH.

A large portion of the second meetings was devoted to bringing the participants up to speed on the details of the options and uncertainties that were modeled. Thus time was spent exploring the characteristics of the individual supply and demand options, as well as proportions by which they were combined into option sets. For example, the Collaborative demand-side management option set consisted of sixteen individual programs targeting different customer classes: residential, commercial, industrial, for existing demand, future demand, and market development. The Enhanced demand-side option set included the same programs as the Collaborative, but was three times as ambitious in its savings targets. Figure 8-4 shows the energy savings associated with each of the two option sets.

Figure 8-4: COM/Electric Demand-Side Option Set Characteristics
Source: AGREA 1990b



Results from an initial set of 48 scenarios provided the vehicle for familiarizing the participants with the behavior of COM/Electric's system, and with our method of presentation. Using a pared down version of the data analysis strategy described in Chapter Four, we first presented univariate results. For example, Figure 8-5 shows the performance of selected strategies along the attribute of sulfur dioxide emissions, given uncertainty about gas prices and customer responsiveness to demand-side programs. This quickly revealed that clean coal was the most robust supply option set, because it was impervious to uncertainty about natural gas prices. While the minimum SO_2 values were similar across strategies, the maxima for strategies with gas were higher than those for clean coal. On the demand-side, the Enhanced DSM option set showed slight benefits over the Collaborative one when coupled with repowering or gas/coal on the supply side. However, increased DSM worked against the clean coal supply option set, leading to higher emissions. It appeared relatively neutral when combined with a gas-dependent supply option set.

The factors influencing sulfur dioxide emissions (see Figure 8-6) helped to explain this story. As in the New England study, high gas prices led to switching towards dirtier, cheaper fuels such as oil#6 in the loading order of power plants. However, since coal was always cheaper than either gas or oil, the coal-dependent strategy was not dramatically affected by the level of gas prices. Further, it was able to displace a significant amount of existing base load oil#6 capacity in the loading order, making coal the new base load technology. On the demand-side, the Enhanced option set in the gas-dependent, repowering, and gas/coal cases displaced new intermediate loaded power plants, never reaching the existing base loaded plants that primarily burned SO_2-producing oil#6. However, in the clean coal case, more DSM displaced new base loaded coal plants, preventing them in turn from reducing the use of existing oil#6-fired capacity.

The participants were also introduced to bivariate scatter plots, which showed that choices among strategies involved tradeoffs, and that uncertainty affected the relative attractiveness of different strategies.

Figure 8-5: COM/Electric Sulfur Dioxide Emissions for a Subset of Strategies
Source: AGREA 1990b

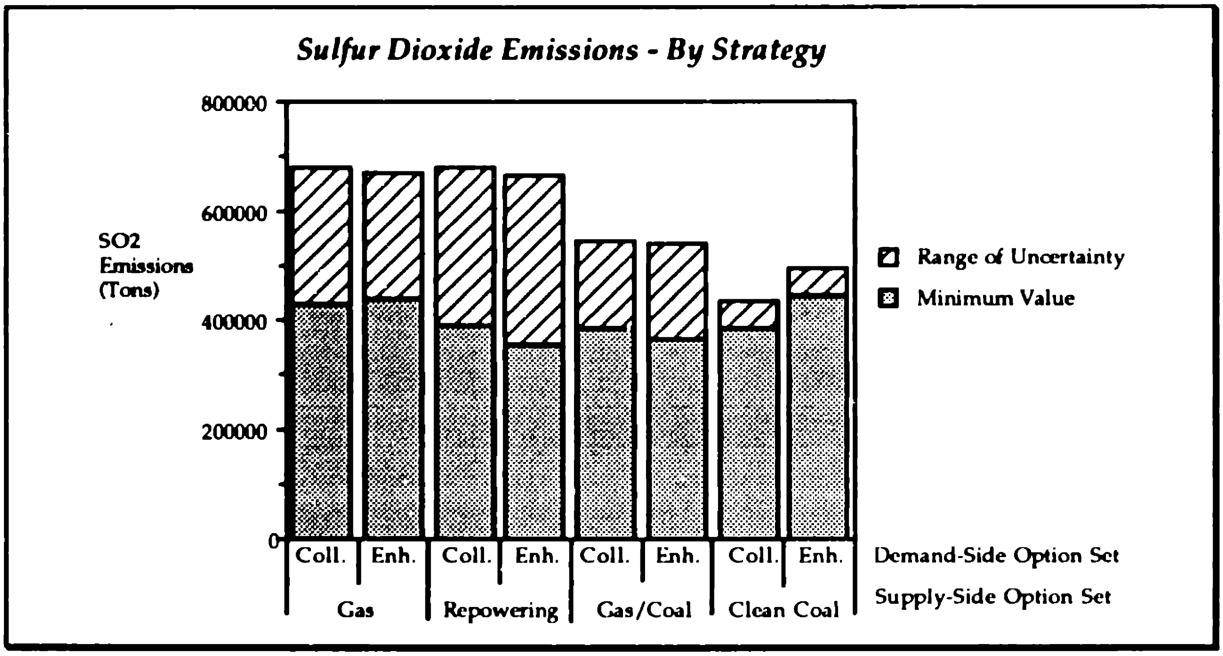
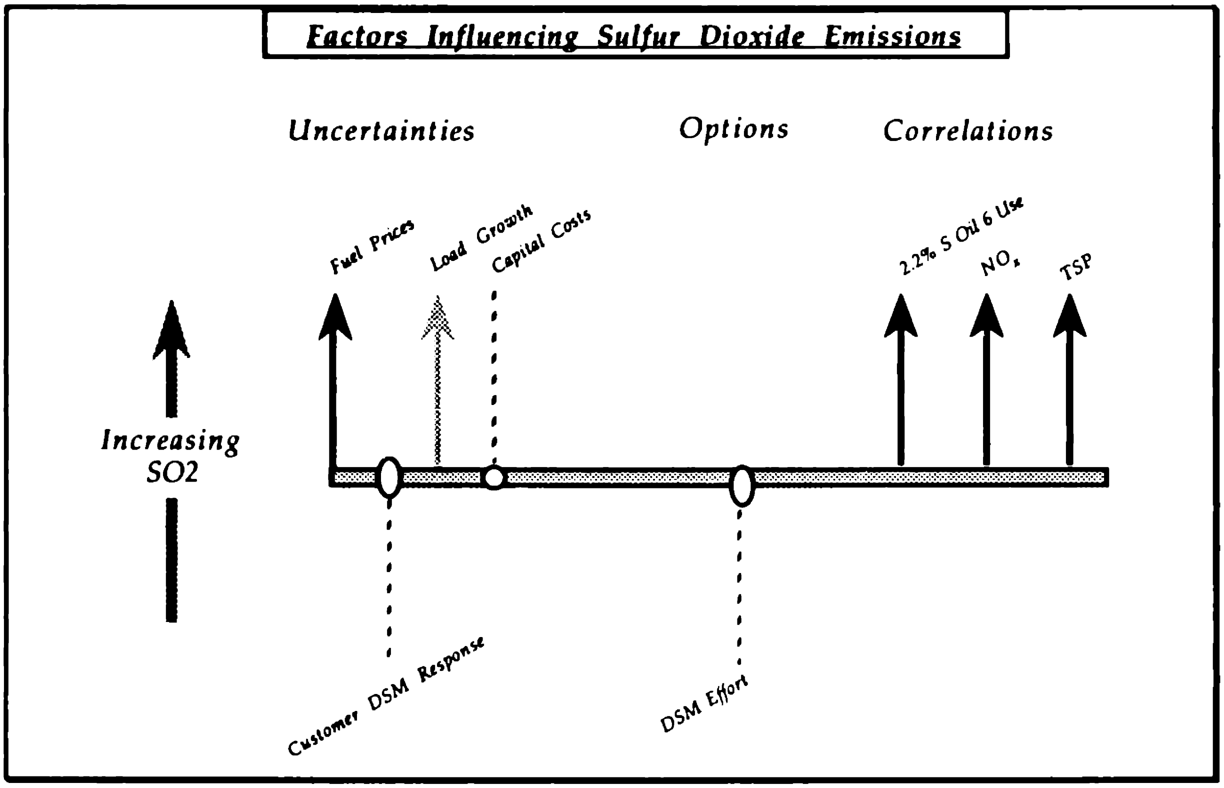


Figure 8-6: COM/Electric Factors Influencing Sulfur Dioxide Emissions
Source: AGREA 1990b



To the surprise of those analysts who had worried that quantitative information would be incomprehensible, the participants asked the types of questions that suggested that they understood the presentation. For example, in the Cambridge meeting, the head of a neighborhood association remarked after reviewing the SO_2 information shown in Figures 8-5 and 8-6, that "when I save a kilowatthour through conservation, it's just a generic kilowatthour. I'd like to save a dirty old kilowatthour instead of a clean new one." In Plymouth, the president of the local radio station noticed that the change in costs across strategies, especially on the supply side, was relatively small. Therefore, he said, "It seems to be worth investing some capital in insuring against fuel risks and other uncertainties."

The participants asked a variety of questions about underlying assumptions not shown in the viewgraphs. For example, participants in both Hyannis and Plymouth wanted to know what the basis for the electric load forecasts was. Likewise, the county commissioner from Hyannis wanted to know what was the existing fuel mix in the COM/Electric system. Similar questions were asked about the connection between fuel use, investments, costs and rates, DSM response, the operating relationship between COM/Electric and the regional electric grid, specific technologies, trends in electric consumption, emissions reduction strategies, the characteristics of different pollutants, the natural gas marketplace, and other things. One participant (Polaroid's facilities manager) even caught an inconsistency between the MIT numbers and COM/Electric's published data on SO_2 emissions from clean coal power plants (COM/Electric's source was more recent).

The good news was that the people who participated in the second set of meetings were curious, attentive, and benefitted from the sessions. The bad news was that attendance was much lower than in the first meetings. There were only four participants each at the Cambridge, Plymouth, and Hyannis meetings. New Bedford had six, although one was a Cambridge person who preferred the New Bedford meeting date. The small turnout (a classic problem in open planning) was ascribed to various causes by the participants. The head of the newspaper in Plymouth said that the slide show in first meeting had been "overwhelming; we were left wondering what we could possibly contribute to such a complex planning task." In direct contrast, the aide to the state senator in Hyannis said the slide show and issues/uncertainties/options discussion had "aimed too low so that people felt they were being asked to make a complex decision based on inadequate information." The Polaroid representative said that "the lack of numbers on the axes of the graphs in the slide show [removed so as not to "scare" a lay public] had left him and others worried that the discussion would be too general to be of value. The COM/Electric vice president then told the participants to pass the word that everyone attending the third meeting would receive a free energy-efficient light bulb as a token of appreciation.

The remaining time in the second meetings was devoted to a questionnaire soliciting the participants' views on the most important attributes to measure, and the types of uncertainties to consider in the planning exercise (see Figure 8-7). The main purpose of the instrument was to find out how to structure the tradeoff analysis discussion in the final set of meetings. The highest priority attributes would form the axes of the initial tradeoff curve, and values shown would be those for the highest-interest future. It would also provide a measure of the importance the participants placed on different attributes, their aversion to different types of risks, and the degree of consensus attending these value judgements.

Figure 8-7: COM/Electric 2nd Meeting Questionnaire
Source: AGREA 1990b

What Are Your Views?

Questionnaire to participants in the COM/Electric-MIT open planning project at end of the second meeting. Answers kept confidential.

Please prioritize these issues in order of their importance for this planning effort: (1=most important, 2=important, 3=less important, ..., 8=least important)

______ Cost of electric service (average level)
______ Cost of electric service (variability)*

______ Reliability/outages (average level)
______ Reliability/outages (variability)*

______ Local site-related environmental impacts/land use/noise/visual

______ Regional environmental impacts/acid rain/smog

______ Global environmental impacts/greenhouse effect

______ Solid/liquid/nuclear waste streams

______ Other (specify)____________________________

Please select the combination of future possibilities that <u>you</u> consider to be the most important for COM/Electric to anticipate in its plans. Check one in each column.

Electric Load <u>Growth</u>		Fuel <u>Prices</u>		Consumer Response to Utility <u>Conservation Programs</u>		Capital <u>Costs</u>	
Low	______	Low	______	Low	______	Steady	______
Med	______			Med	______		
High	______	High	______	High	______	Higher	______

Your name (optional) ____________________________

Please hand this in before you leave. Thank you for your input.

* The average level of cost or reliability is its magnitude, on average, over the long run. Its variability reflects the degree to which it changes from one year to the next, and its sensitivity to uncertainties.

Third Meetings: Final Results and Eliciting Preferences

The final set of advisory group meetings began in Cambridge on May 14th, 1990. Their goal was to understand the participants' preferences regarding COM/Electric's planning choices. The specific agenda included reviewing the scope of the study, reporting on the participants' views as shown in the questionnaire, evaluating the performance of the options to thereby identify the small set of "best strategies", and discussing tradeoffs – characterizing the preferred strategy(ies) from the participants' points of view.

All 720 of the scenarios described in the previous section had been run for this meeting. Thus, the multi-attribute performance of forty strategies across eighteen different futures was available to be shared with the groups. The questionnaire responses guided the presentation of this material, as described above. Table 8-8 shows how the participants prioritized the issues in order of their importance for this planning effort. Overall priorities were based on the rank sums (not scores as in previous questionnaires) of individual questionnaire responses, including three questionnaires mailed by people who had not been able to attend the previous meeting.

Table 8-8: COM/Electric Issue/Attribute Prioritization

Priority	Issue	Attributes, or Measures	Rank Sum
1	Regional Environment	SO_2, NO_x, and Particulate Emissions	58
2	Cost of Electric Service	Total Cost of Electric Services	69
3	Reliability	Hours in NEPOOL Emergency Oper. Lev.	80
4	Global Environment	CO_2 Emissions	91
5	Variability of Costs	Maximum Ann. Increase in Cost of Service	94
6	Local Environment	No., Size and Footprint of New Plants	103
7	Waste Streams	High Level Wastes	105
8	Variability in Reliability	Minimum Annual Reserve Margin	116

Only the top two attributes – regional environment and cost of service – were consistently highly ranked across service districts. Others such as reliability, global warming, and waste streams were highly ranked in some meetings and ignored in others. The participants' profession also seemed to matter, with business people, for example, placing a higher emphasis on cost than others. The data set as a whole had a Friedman test statistic of 22.65, which implied consistency at the .998 level of probability (assuming a chi-square distribution with seven degrees of freedom, per Pindyck & Rubinfeld, 1981). Based on these responses, the analysis team focused first on SO_2 and cost tradeoffs, and later brought in reliability and CO_2 emissions.

According to the groups, the most important future possibilities for COM/Electric to anticipate in its plans deserved to be prioritized as shown in Table 8-9. Overall priorities were based on the sums of individual questionnaire responses.

Table 8-9: COM/Electric Uncertainty Prioritization

Level	Uncertainty	(Votes Received/Total Votes)
Low (2)		
Medium	Electric Load Growth	(12/21)
High (7)		
Low (6)		
High	Fuel Prices	(15/21)
Low (3)		
Medium (9)		
High	Customer Response to Util. Conserv. Progs.	(9/21)
Steady	Capital Costs	(16/21)
Higher (5)		

The highest-interest future, based on the questionnaire responses, was that with Base load growth, Base capital costs, High DSM responsiveness, and High natural gas prices, or BBHH in the modeling terminology. This showed fuel-side risk-aversion, but optimism regarding DSM investments. This was the future for which the initial tradeoffs were presented.

Before tackling real tradeoff curves with the advisory groups, the facilitator covered several conceptual points to assist their thinking. First, the concept of dominance was introduced using Figure 8-8. In a non-probabilistic case, strategies 'b' and 'c' dominate 'd' but not each other for the two attributes shown. Strategy 'a' does not dominate 'd' and is not itself dominated by any other strategy shown. Using this decision rule, the universe of strategies could be broken into a dominated set and a decision set, defining the frontier along which tradeoffs should be made.

Figure 8-8: Evaluating Tradeoffs
Source: AGREA 1990a

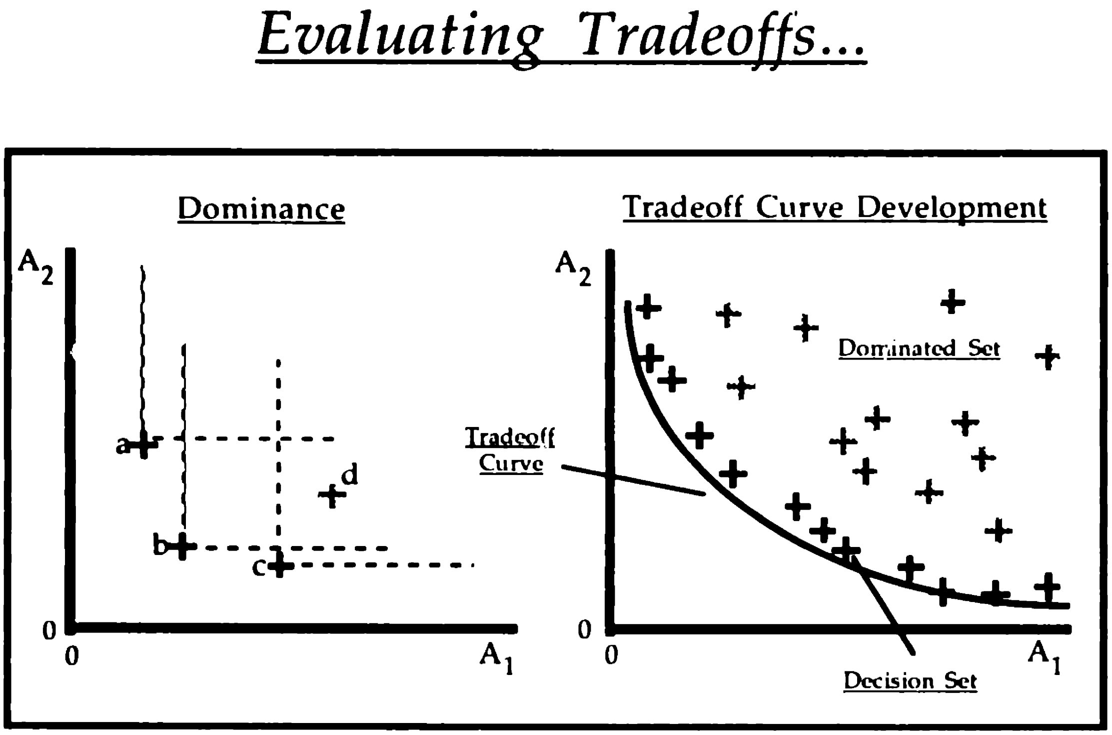
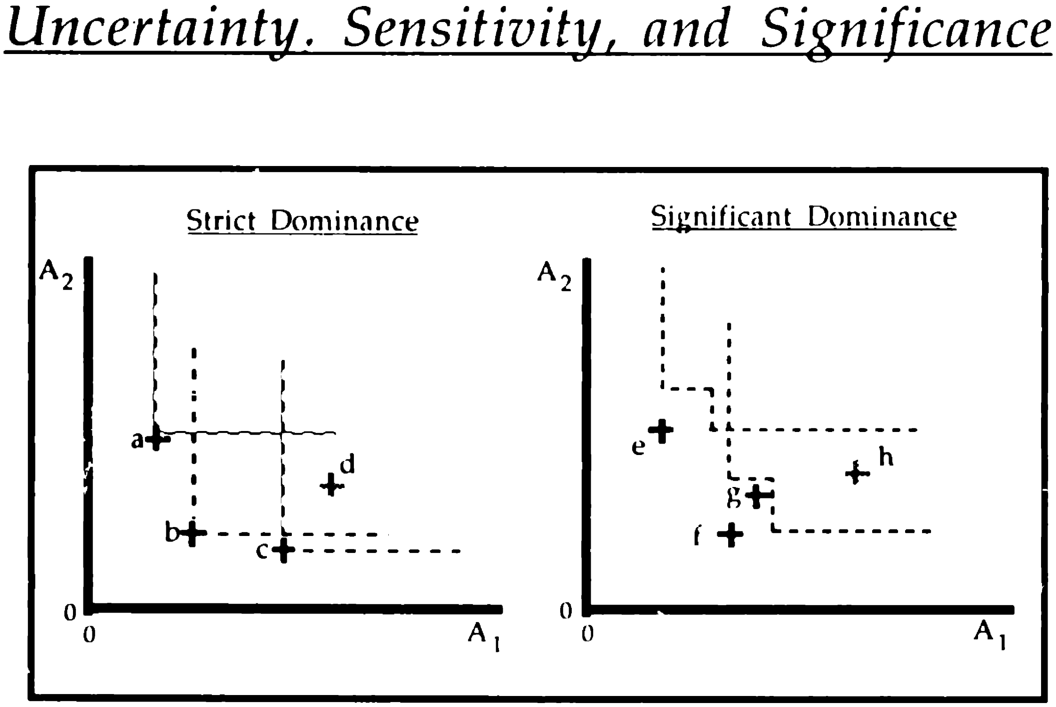


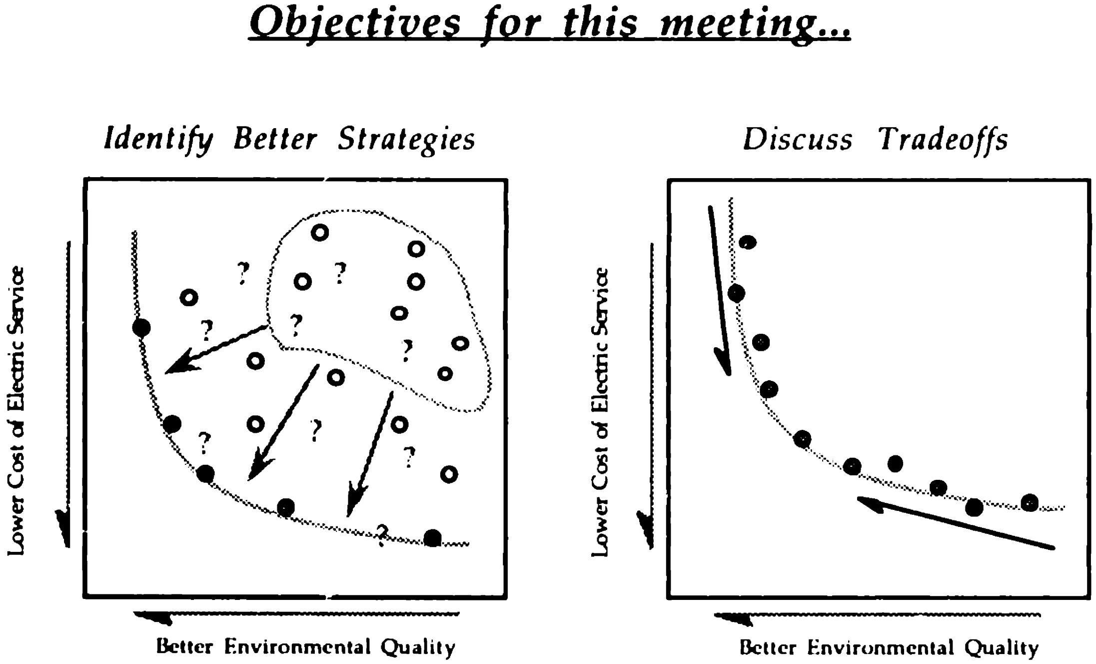
Figure 8-9 introduced the problems of uncertainty, sensitivity, and significance to the groups. Uncertainty could make it impossible to locate a strategy as a single point in multi-attribute space as was done in the strict dominance graph on the left. The graph on the right shows how dominance works under uncertainty – there is a bandwidth surrounding each point representing the uncertainty in its coordinate values. Thus, while strategy 'f' significantly dominates 'h', it does not significantly dominate 'g' because 'g' lies within the bandwidth of uncertainty. Different parties' sensitivities to changes in attribute values could lead to the same effect – the difference between strategies 'f' and 'g' may be functionally irrelevant to some parties – again making the difference insignificant.

Figure 8-9: Uncertainty, Sensitivity, and Significance
Source: AGREA 1990a



The facilitator then closed with two graphs (see Figure 8-10) specifying the objectives for this advisory group meeting; namely, to identify the better strategies, and then discuss the tradeoffs so that a choice among the strategies lying on the frontier could be made. The responsibility for the left-hand graph, improving the multi-attribute efficiency of electric service provision, belonged primarily to the analysis team; while the equity and normative decisions embedded in the right-hand graph belonged to the advisory groups.

Figure 8-10: Objectives for This Meeting
Source: AGREA 1990a



Objectives for this meeting...

Identify Better Strategies

Discuss Tradeoffs

Discussion of real tradeoff curves then commenced. Starting with the highest priority attributes (cost and SO_2 emissions) using values for future BBHH, the performance of the various strategies was examined. Figure 8-11, for example, revealed several important things. In this figure the strategies were identified by supply option set, so that there were four of each (2 DSM option sets x 2 reserve margins). The figure clearly showed that several strategies were inferior: all of the 'H's' and 'J's', for example.

Supply option set 'H', or Canal 3, was based on a proposal by one of the COM/Electric planners to add a clean coal unit to the existing Canal site, and to convert the existing units from oil#6 to coal gas by building an over-sized coal gasification system. The high capital costs and low operating efficiency of such an arrangement made it an inferior option.

Supply option set 'J', or solar photovoltaics with gas, was proposed by the advisory groups, and consisted of placing solar cells on 50% of the existing residential roof area and 20% of the commercial roof area in the COM/Electric service territory by 1995, at a unit price of one half of today's price. The remaining capacity needs would be met with gas-dependent technologies. The weak point in this concept turned out to be the fact that COM/Electric's annual peak demand occurred on winter evenings when the sun did not shine; therefore the photovoltaic arrays did not avoid the expense of building new capacity, but only reduced the annual energy production by other sources.

Strategies lying along the frontier consisted of low sulfur oil #6 and clean coal (B, D, F, G). The low sulfur oil#6 strategies (B, D) cost about 5% more than the clean coal strategies (F, G), but had 70% lower SO_2 emissions.

A close look at the patterns within each supply option set grouping of four strategies revealed important information about the demand-side. The Enhanced DSM option set (_E_) always had lower costs than the Collaborative (_C_) with approximately the same level of SO_2 emissions. Thus the Enhanced strategies claimed the frontier in every case, except 'BCH/BEH', when both made it.

Examining the groupings of four for the effects of reserve margin was also useful. The high reserve margin strategies (__H) always had lower SO_2 emissions and a slightly higher cost than those with the lower reserve margin

(__L). Looking at the (B__) grouping, most participants agreed that the preferred combination was to choose Enhanced DSM to lower costs, but then to "buy" some SO2 reduction by selecting the higher reserve margin, thus choosing strategy 'BEH', for example.

The benefits of this approach were reinforced when the participants viewed a tradeoff graph incorporating the third-ranked attribute of reliability (see Figure 8-12). There the high reserve margin cases (__H) consistently claimed the tradeoff frontier from the lower reserve margin strategies (__L).

The fourth-ranked attribute was CO_2 emissions. The global environment vs. regional environment tradeoff shown in Figure 8-13 made decision making more difficult. While some previously favored strategies such as 'BEH' remained on the frontier, CO2 concerns brought nuclear (I), a non-fossil option, into the picture. This in turn brought demands for nuclear wastes, heretofore ranked low, at seventh priority, to be shown as a decisionmaking attribute.

When planning for the meetings, the analysis team discussed the idea of eliciting the participants' preferences regarding which decision rule to use in dealing with uncertainty. Should tradeoffs be weighed using the most popular future, based on the questionnaire? Should a risk-averse (maximin) approach minimizing down-side risks be used, by weighing tradeoffs based on the worst future? Should an optimistic (maximax) approach maximizing the up-side benefits be used, by weighing tradeoffs based on the best future? Or should an approach emphasizing accountability (minimax regret) that minimized the difference between the best and worst futures be used? The team decided to simply show all three futures to the advisory groups, and let the decision rule remain implicit in their final choice of a strategy.

Figure 8-11: COM/Electric Total Cost of Electric Service vs. SO_2 Emissions – by Supply Option Set
Source: AGREA 1990a

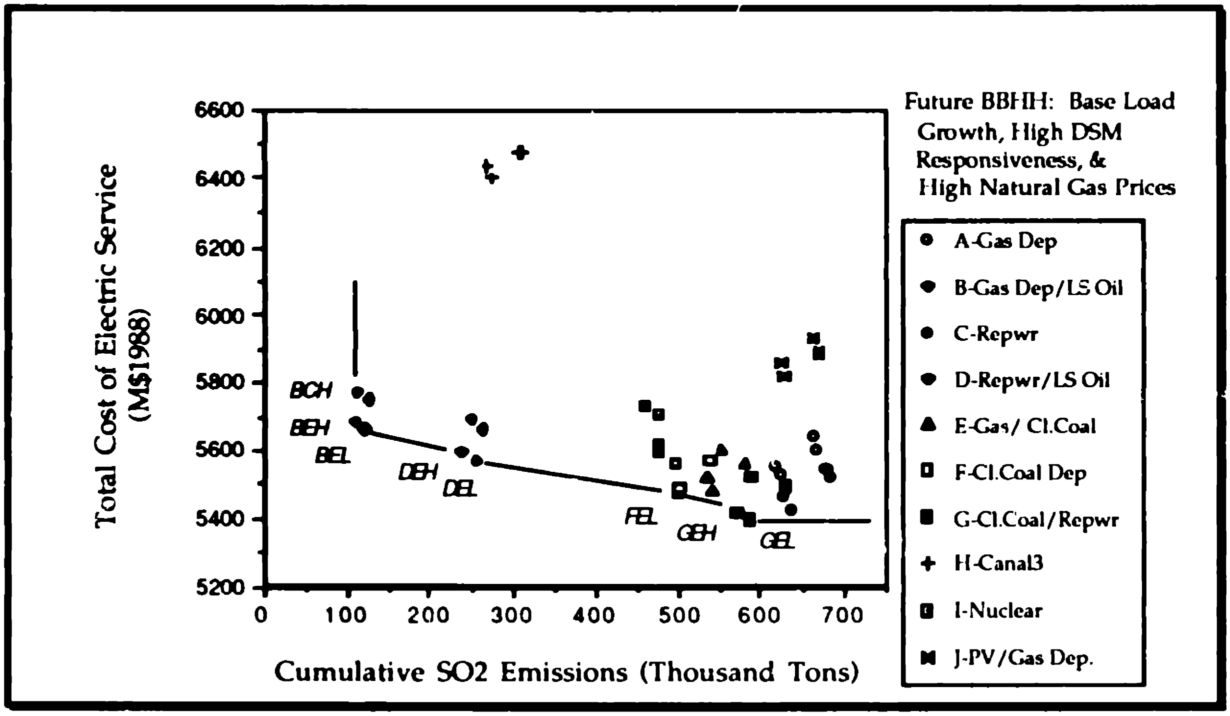


Figure 8-12: COM/Electric Total Cost of Electric Service vs. Reliance on Emergency Interruptions– by Reserve Margin
Source: AGREA 1990a

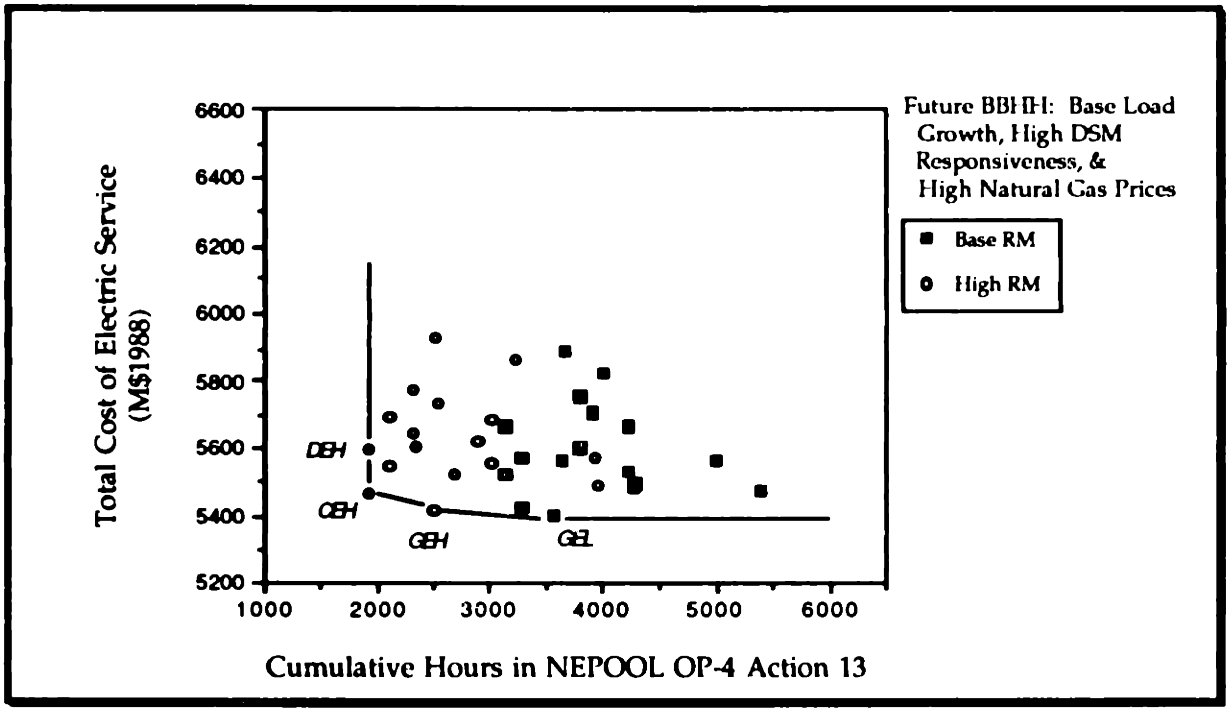
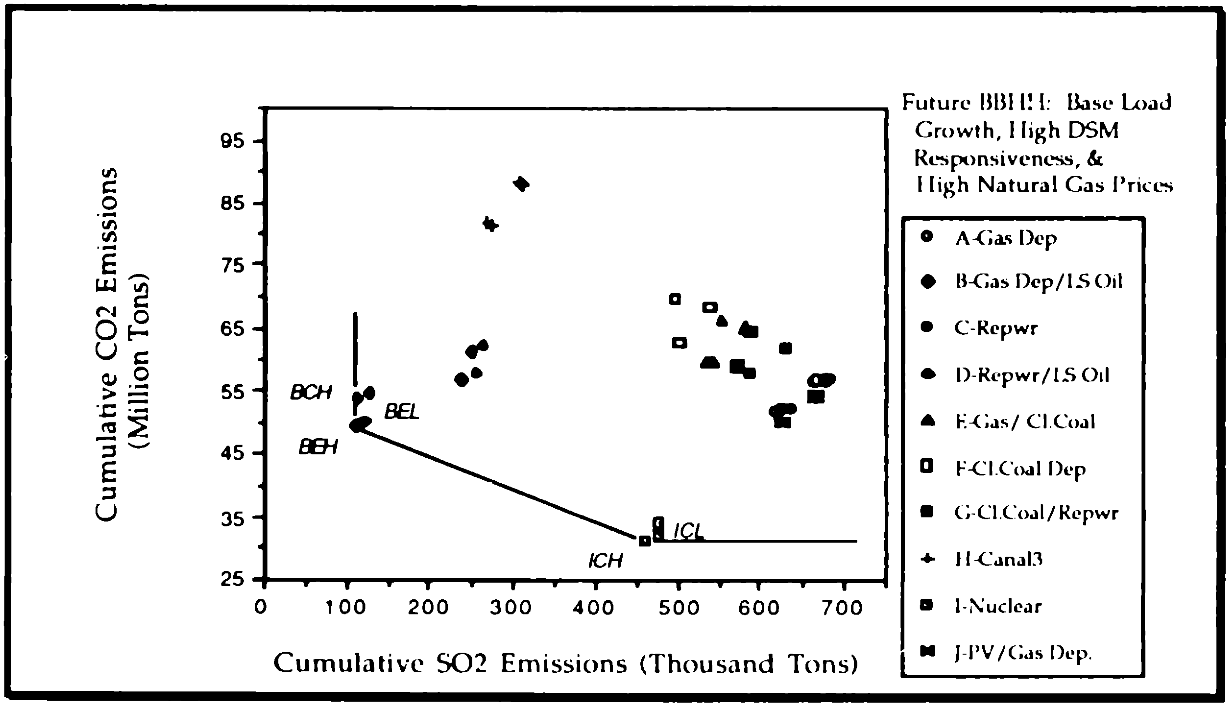


Figure 8-13: COM/Electric CO_2 vs. SO_2 Emissions
- by Supply Option Set
Source: AGREA 1990a



The effects of uncertainty were explored by showing (in Figure 8-14) the decision sets or tradeoff frontiers, for each of three futures: the favorite (BBHH), the worst (HBLH), and the best (LBHL). Bracketing the results by displaying the best and worst futures made the participants more comfortable with the robustness of the findings. Some of the most interesting strategies (BEH, for example) maintained the same relative positions in all three futures.

However, the comparison across futures also revealed the vulnerability of some strategies to uncertainty. Figure 8-15 showed the migration of strategies through cost/SO_2 space for different futures. As can be seen, they all migrated about the same distance along the cost axis between the best and worst futures. Differences were revealed along the SO_2 axis.

Figure 8-14: COM/Electric Total Cost of Electric Service vs. SO_2 Emissions – by Supply Option Set for Favorite, Best, and Worst Futures
Source: AGREA 1990a

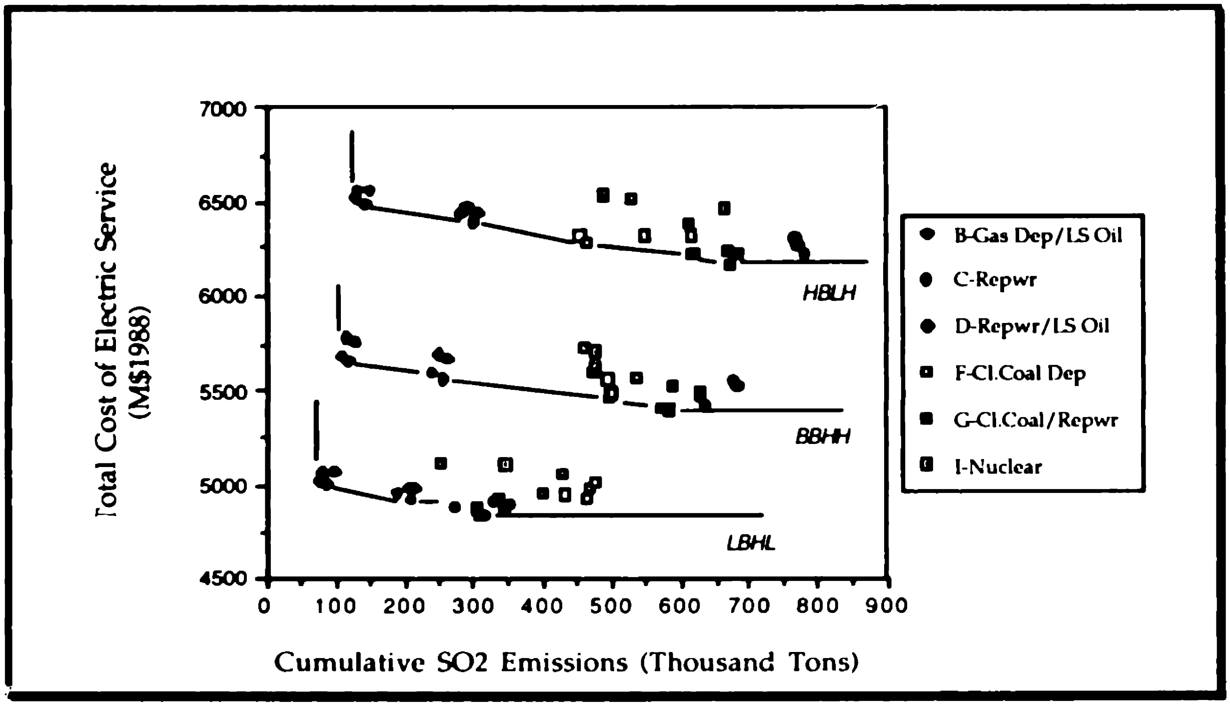
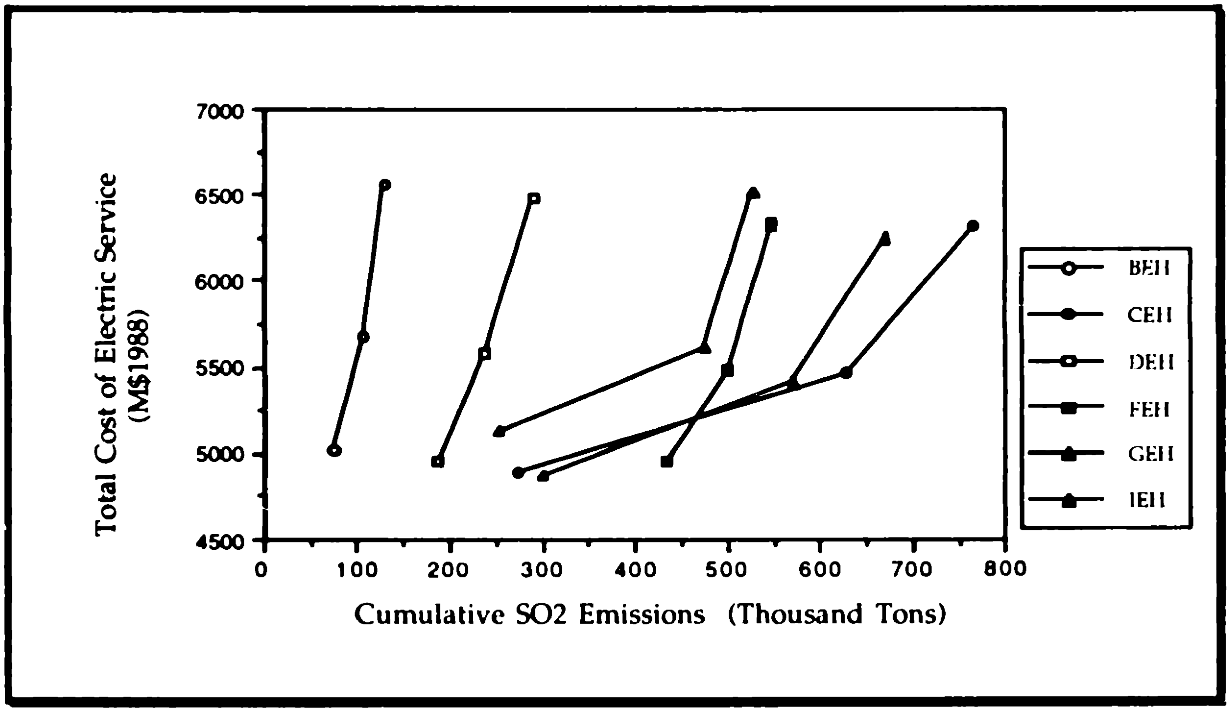


Figure 8-15: COM/Electric Total Cost of Electric Service vs. SO_2 Emissions – Migration across Favorite, Best, and Worst Futures for Dominant Strategies
Source: AGREA 1990a



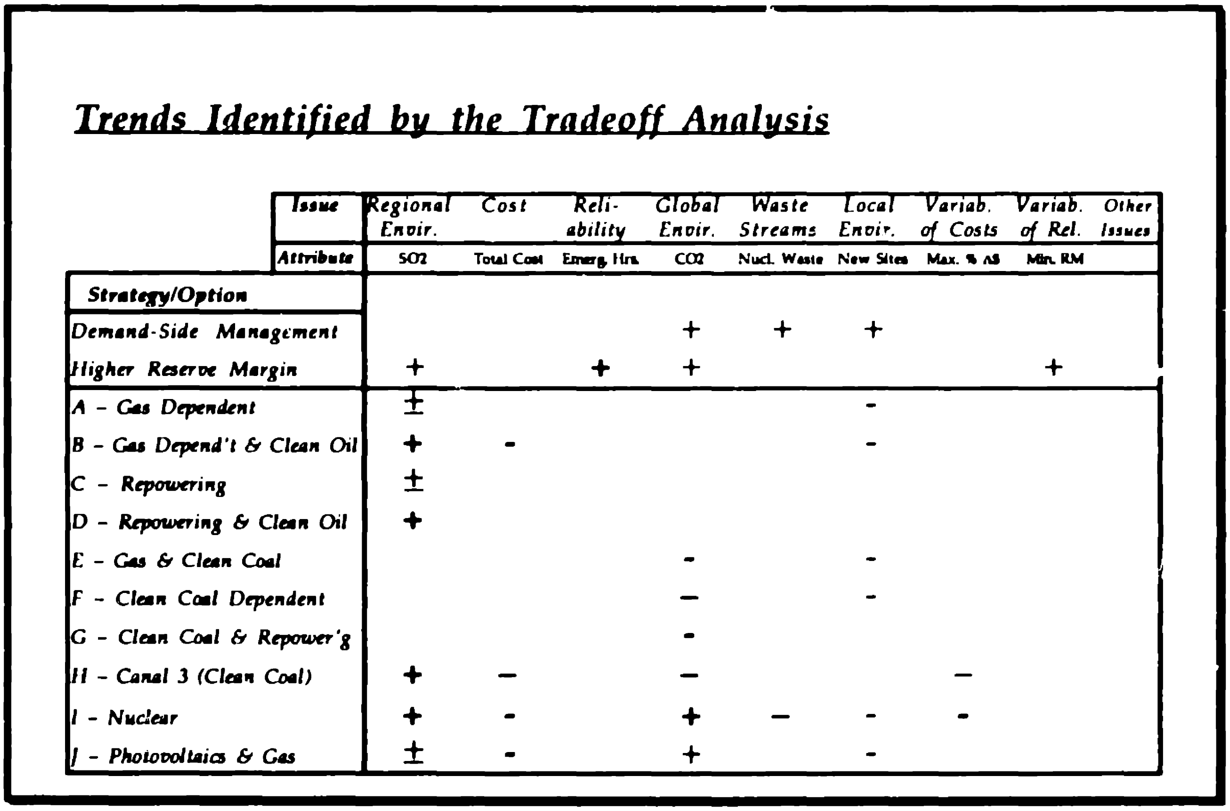
Strategies 'CEH' and 'GEH' showed much larger SO_2 emissions in the worst future than in the best future in Figure 8-15. Both of these strategies included repowering of existing plants with gas, and using expensive oil#2 as the backup fuel. These strategies were therefore particularly vulnerable to changing gas prices, because with high gas prices the dirtier existing plants burning cheap oil#6 would operate instead, leading to higher SO_2 emissions. Similar strategies incorporating low sulfur oil#6 did not suffer this weakness (compare CEH to DEH, for example).

The participants waded through the graphs shown here, plus many others, in sessions that were designed to be much more interactive than the second set had been. Backup graphs explaining the effects of uncertainty and reviewing modeling assumptions were all available if needed by the group. Viewgraphs of background information available for use in the presentations also included the univariate performance of strategies for a large variety of attributes ranging from the consumption of specific fuels to levels of spent nuclear waste. Most of the backup material was not needed, because most questions were adequately answered verbally.

To assist the participants in selecting a their preferred strategy, a table summarizing the trends identified by the tradeoff analysis was presented (see Table 8-10). A '+' symbol meant that the strategy helped along that attribute (where lower was better), a '–' symbol meant that it hurt, a '±' symbol meant that the outcome was highly sensitive to uncertainty, and a blank space meant that the strategy made little difference one way or the other. Larger and bolder symbols indicated larger impacts.

One reason for providing the summary table was to ensure that participants considered the whole range of attributes in their decisions. However, most of the groups found that the information in the matrix had been reduced too much to be useful, and that, when creating it, the analysts had imposed subjective judgements different from their own, thereby tainting it. They therefore preferred to work off of Figures 8-11, 8-13, and 8-14 in making their decisions.

Table 8-10: Trends Identified by the Tradeoff Analysis
in the COM/Electric Data Set
Source: AGREA 1990a



Trends Identified by the Tradeoff Analysis

Issue	Regional Envir.	Cost	Reli-ability	Global Envir.	Waste Streams	Local Envir.	Variab. of Costs	Variab. of Rel.	Other Issues
Attribute	SO2	Total Cost	Emerg. Hrs.	CO2	Nucl. Waste	New Sites	Max. % Δ$	Min. RM	
Strategy/Option									
Demand-Side Management				+	+	+			
Higher Reserve Margin	+		+	+				+	
A - Gas Dependent	±					-			
B - Gas Depend't & Clean Oil	+	-				-			
C - Repowering	±								
D - Repowering & Clean Oil	+								
E - Gas & Clean Coal				-		-			
F - Clean Coal Dependent				−		-			
G - Clean Coal & Repower'g				-					
H - Canal 3 (Clean Coal)	+	−		−			−		
I - Nuclear	+	-		+	−	-	-		
J - Photovoltaics & Gas	±	-		+		-			

The analysts sought to develop a method for the facilitator to use in eliciting the participants' preferences that revealed the groups' valuations of environmental externalities. One part of this method was to put cost on one axis of many of the tradeoff plots, so that the tradeoffs of various environmental attributes against cost would be clear (see Figures 8-11, 8-14, and 8-15, for example). A second part of this method was in the voting order: they would start with the cheapest strategy, and tally the number of votes for each strategy in order of increasing cost. This would reveal: (1) the implicit valuation, or shadow price of the environmental attribute in dollar terms assuming all else constant, and (2) any thresholds or non-linearities in attribute valuations. The third part of this method was to develop "synonym attributes" to help the participants get a feel for what the differences among strategies really meant. For example, in addition to showing graphs using total cost of electric service as the cost attribute, the analysts also had backup graphs displaying ¢/kWh differences, unit cost of electric service differences, and percent cost differences. This valuation method was not closely followed in practice, for reasons discussed below.

How did the decision making exercise turn out? The Cambridge meeting, as before, had four participants, with a fifth attending the New Bedford meeting because of a scheduling conflict. The meeting ended in consensus, with strategy 'BEH' (gas-dependent supply capacity, clean oil#6, Enhanced DSM, and high reserve margin) being the first choice, followed by 'DEH' (which included repowering). They also expressed interest in seeing a hybrid strategy consisting of 'GEH' plus clean oil#6 for existing plants would perform. The nuclear option (IEH) was taken off the table on the strength of one participant's demand to "throw it out" and no objections from the other participants not to do so.

The Plymouth meeting on May 15th, 1990 had only two participants, so the time was used for a discussion of how to make an open planning process work, instead of the technical discussion of tradeoffs.

There were five participants at the Hyannis meeting, and they engaged in a fairly spirited discussion of tradeoffs. They were able to reach a consensus on the concept of paying higher electricity bills to clean up the environment, at least to the 6% range shown in Figure 8-11 as the difference between the cheapest and least-SO2-emitting strategies (GEL and BEH). They also endorsed the concepts of high-DSM and a higher reserve margin. However, they were unable to reach consensus about whether to minimize SO_2 emissions by choosing a strategy such as 'BEH' or to minimize CO_2 emissions with a hybrid strategy using new nuclear and clean oil#6 in existing plants. One of the sticking points in this discussion was that nuclear wastes were an overriding concern of one of the participants, who preferred the known problems of SO_2 and CO_2 emissions rather than the less-known problem of nuclear waste disposal.

The final New Bedford meeting had a low turnout, with only three participants, including one from Cambridge. However, the discussion was quite animated, and the group was unable to reach a consensus. They did agree on the value of high-DSM and a higher reserve margin, but could not agree whether to choose a low-cost or low-emissions supply option. While all agreed that an 80% SO_2 reduction for a 6% cost increase sounded quite cost-effective, an industrial electricity customer pointed out that industries worked very hard to shave 6% off of their electric bills, that this amount significantly affected their competitiveness. All of the participants said that they "needed more time to chew on it and toss it around."

Several things thus hindered a definitive outcome of the experiment. First, the small number of participants negated any possible claim to having elicited truly representative public preferences. Second, seemingly better hybrid options were invented during the preference elicitation process. These would have to be modeled and placed on the tradeoff curves before the participants would be willing to negotiate tough strategy-specific tradeoffs between cost and environmental quality. Finally, the participants ran out of time. They were just warming up to their arguments when the last meetings ended; participants in New Bedford, for example, stayed on for an extra hour of discussion with the analysis team about the experiment.

Next Steps

The initial rounds of external advisory group meetings provided a test of the credibility and usefulness of both the open planning approach and scenario-based multi-attribute tradeoff analysis. A series of steps are being taken to continue the process that was begun with this experiment.

The computer modeling tools developed at MIT for the project are being transferred to COM/Electric, and company planning staff are being trained in their use. To test the success of this technology transfer effort, the COM/Electric planners are running additional scenarios to round out the data set generated for the advisory group meetings, including the new hybrid strategies. Two members of the planning department attended the advisory group meetings, so that they also learned about the context for the work.

The MIT team is writing up the results of the first experiment, and it will be shared with all of the participants and the press. An abridged form of the results may be sent to all customers in the form of a bill stuffer.

Other efforts to elicit public participation in the planning process are planned, using several vehicles. Participants in the initial experiment offered a variety of suggestions. First was to hold another round of meetings, but to organize them as one long session in each district rather than three, and to jump right to the preference elicitation portion, skipping over the issue definition and scenario development phases. Second, there was a proposal to broadly elicit public opinion by mailing a questionnaire in all electric bills. A third approach favored having the utility commission a survey that reaches a statistically significant random sample of customers, to ensure that representative views are heard.

The integrated resource planning regulations being issued by the Massachusetts DPU (1989) include a pre-filing settlement process. During technical sessions at the beginning of each planning cycle, a utility company is supposed to seek a consensus on its planning assumptions, on a strategy defining the resource blocks that will be put out for bids, and on the criteria for evaluating bids. The scenario-based multi-attribute tradeoff analysis technique is expected to be used in these sessions.

Finally, scenario-based multi-attribute tradeoff analysis is being included in the improved framework for integrated resource planning that was demanded by the Massachusetts Energy Facilities Siting Council in its previous review of COM/Electric's planning approach. This will test its acceptability in a formal regulatory context.

Efficacy of the COM/Electric Open Planning Project

The COM/Electric open planning project was initiated for several reasons, as stated earlier: to improve the credibility of the Company's resource planning method, to better integrate demand- and supply-side planning, to include environmental impacts in the planning process, and increase the level and quality of public participation. The initial experiment with four customer advisory groups revealed a number of useful things about both the analysis technique and the process.

The experiment demonstrated that it was feasible to conduct exhaustive analysis in a scenario-based multi-attribute tradeoff framework with a quick turn around time – just over two months separated the first advisory group meeting from the last. In that time, issues were defined, 720 scenarios were developed and analyzed, presentations replete with graphics were prepared, and a dozen meetings were facilitated. It took a year to get the integrated modeling system up and running, but once in place, the scenario analysis task was manageable.

The experiment demonstrated the value of the technique for finding robust strategies that: (1) integrated demand- and supply-side options together into a coherent plan, (2) explored the effects of uncertainty on performance, and (3) incorporated consideration of environmental impacts. This suggests that it may be a useful part of the overall planning method that the company is developing to satisfy regulatory concerns.

Some of the information sharing techniques used in the presentations worked, while others did not. They are listed and rated in Table 8-11. The biggest single surprise to the analysts was that most participants preferred to look at scatterplot tradeoff curves rather than summary matrices when making choices. Even though one participant said that the dots representing strategies "looked like bugs squashed on the screen" he still liked that form of display.

At the end of each of the third sessions, the participants were asked the answers to a series of wrap-up questions. These are discussed below.

Was there a consensus? The answer was yes in Cambridge, but it was a qualified no elsewhere. In Plymouth, the president of the radio station said that he felt uncomfortable deciding among strategies; that he was willing to offer philosophy but not make technical choices. In Hyannis, participants agreed on some "all-gain" components (high-DSM and higher reserve margin) and were willing to make final choices among strategies, but could

Table 8-11: Efficacy of Techniques as Applied on the COM/Electric Project

Techniques Used on the COM/Electric Project	Useful to Analysis Team?	Useful to Advisory Groups?
Line graphs to show trends over time	Yes	Yes
Column graphs to show performance of strategies along a single attribute, plus the range of uncertainty	Yes	Yes
Arrow charts to show the factors influencing an attribute's value, and the direction of that influence, including uncertainties, options, and correlations	Yes	Yes
Scatterplots to show tradeoffs between two attributes. for many strategies, within a single future	Yes	Yes
Scatterplots to show tradeoffs between two attributes for many strategies, across several futures	Yes	Yes
Line plots to show migration of strategies in two-attribute space across futures	Yes	Yes
Matrix (strategies by attributes) summarizing trends identified by the tradeoff analysis	Yes	No
Questionnaire eliciting preferences	Yes	Yes
Voting by show of hands for priority issues	Yes	Yes
Showing results for the best and worst futures to bracket the analysis of uncertainty	Yes	Yes
Asking the participants to prioritize attributes	Yes	Yes
Asking the participants to prioritize uncertainties for utility to anticipate in its plans	Yes	Yes
Asking the participants to choose a specific preferred strategy	Yes	No
Asking participants to characterize a preferred strategy in multi-attribute space	Yes	Yes
Sharing intermediate results with participants	Yes	No

only agree on a philosophical point – that increasing costs by 7% to reduce environmental damage was a good idea. In New Bedford there was also agreement on more DSM and the higher reserve margin, but not on the level of cost vs. environment tradeoff to make. Participants pointed out that there was agreement that certain strategies (such as Canal 3 (H)) could be ruled out.

Were there differences of opinion? The answer here was unanimous – yes. Participants held different views on which attributes were most important, which uncertainties ought to be planned for, and which differences in attribute values were significant. However, this did not prevent them from agreeing about some things such as the value of demand-side management and a higher reserve margin.

Were the presentations comprehensible? The slide show in the first session received low marks from many people. One participant said it was "overpowering," while another said that "it didn't offer enough substance to busy people who, it seemed, were being asked to make complex decisions on the basis of inadequate information." These same people said that the second and third meetings resolved both problems, and that the presentation graphics in those meetings were generally good. Specific parts of those presentations were rated in Table 8-11 above.

Were the presentations credible? The answers to this question were largely yes. Several people said that the movements of points on the graphs registered intuitively, and that it was useful to be shown the big picture. One person said that the credibility of the results was "unquestioned," but others added qualifiers, one asking herself "what was left out of the model?" while another stated that "the presence of academics built the credibility." During the meetings there were lots of questions about the modeling assumptions used that were answered either immediately or in subsequent meetings. One participant felt that the long, three session process was important in establishing credibility, saying "it can't go into a single session, you'll just get blank looks." However, another insisted that "perception is the key to credibility, not strength of detail."

Were the sessions useful, constructive, and on the mark? The participants provided a variety of answers. One said that "the process could have gone on without the participants – except for the attribute prioritization stage." Another "appreciated the openness of the process, but felt uncomfortable offering untutored opinions." Another stressed its educational value, saying, "I learned what to do in my own home regarding conservation, and that there exist tradeoffs between cost and the environment." Similarly, another said "a different understanding of the power industry has certainly developed in me." For one participant, it was refreshing "to get off single option solutions" and look at multi-option strategies, and to identify some "win-win situations." Another commented that he was glad that the utility sought feedback on its plans, and appreciated the need to get into the complexities of the problem, but felt that the utility should make the expert choice after asking peoples' general preferences. He used the analogy of the auto mechanic, who "is the only one who knows how the engine works" and who should therefore fix the engine.

All of these comments suggested that, at a minimum, the meetings had public relations value. In fact, several of the participants said "what's going to happen with this input?...Don't let it die here...Get across to the public that COM/Electric is trying to get people involved."

Participants, while mentioning that the "canned" first meeting had been something of a turn-off, also pointed out that "attrition rates are high in all public meetings' and that it probably will be necessary to develop a multi-faceted program to keep in touch with people. Several stressed the need to ensure that a more representative sample of the public should participate, including especially the poor elderly and young families for whom a 6% price increase might be significant.

In conclusion, the initial experiment with open planning at COM/Electric seemed more successful at getting public input for prioritizing attributes and assessing risk aversion than for achieving consensus on specific planning choices involving tradeoffs. Where all-gain outcomes were revealed, as with high-DSM and higher reserve margins, consensus was possible. Where tradeoffs had to be made, it was more difficult. Both more time and more analysis (of hybrid strategies) were needed. The process certainly inspired both the participants and analysts to suggest improved hybrid strategies, such as clean coal with repowering and low sulfur oil, plus high-DSM and higher reserve margin. As such, it played a vital role in spurring inventiveness in the planning debate, and in improving the image of the company, but did not reach closure on decision making.

9. CONCLUSIONS & RECOMMENDATIONS FOR FUTURE RESEARCH

This research evolved from the premise that planning efforts can enter paralysis when a needed consensus is not reached, and that consensus building cannot succeed unless the inventiveness of the stakeholders in the debate can be spurred. Three major impediments to such creativity were identified – controversy, uncertainty, and technical complexity. I suggested that contentiousness could be overcome by opening up the planning process, and that uncertainty and technical complexity could be managed with the help of special analytic tools.

A review of traditional tools showed that they were typically designed to support a single dictatorial decision maker rather than a collaborative process, and thus failed to provide timely information packaged in a useful way. The scenario-based multi-attribute tradeoff analysis technique outlined in this research was designed specifically for use under conditions of controversy, uncertainty, and complexity. It handled controversy by measuring the multiple attribute impacts of options under the conditions of greatest interest to different stakeholders, thus revealing the tradeoffs associated with each option. It handled uncertainty by looking at a range of possible future outcomes. The process managed technical complexity by providing an expert analysis team to ensure adequate technical detail, while minimizing the "black box" nature of modeling by exposing assumptions to public scrutiny, and flagging areas where value judgements had to be made.

This chapter discusses the lessons learned during this research about controversy, uncertainty, complexity, neutral parties, and the role of the analyst. A revised analytic framework incorporating this information is then presented, followed by recommendations for future research and conclusions.

Lessons Learned

The application of this approach to two electric power planning projects pinpointed several practical strengths and weaknesses. Other projects encountering controversy, uncertainty, and complexity can benefit from the lessons learned in these cases.

Controversy

The New England project did not get under way until policy paralysis became painful for the region during the summers of 1987 and 1988. Evidence of the tight capacity situation then became visible to the public, as emergency operating procedures such as voltage reductions and load curtailments were implemented dozens of times more often than in previous years. We needed a crisis to precipitate the cooperative planning effort. This is likely to be true in general.

Of course, once the stakeholders understood the need for consensus on a long term strategy, they supported this *ad hoc* project financially and politically. Individually, they also expressed disappointment – but no surprise – that the existing institutional arrangements had failed to bring this about. The crisis induced some regulatory reform (see MA DPU 89-239, for example). It also produced calls for a permanent long-term regional planning agency to be set up. Obviously, if such an agency existed, it might be able to avoid future crises by circumventing future planning paralysis. Where the political will can be mustered, reforming our institutions to do planning instead of crisis management seems quite worthwhile.

While the political viability of such an agency in New England is highly debatable – the governors of the six states have always been loathe to give up sovereignty – the continuing need for cooperative planning is clear. Future crises loom on the horizon as the electric power industry undergoes restructuring, and traditional sources of supply (from existing power plants to power purchases) become unavailable. A regionwide analytic capability is also needed regardless of whether there is controversy, because the electric power grid operates on a regional basis. The difficulties in understanding environmental tradeoffs, the increased levels of environmental regulation, plus the environmentalists' previous record of success in stopping projects mandate the capability to evaluate environmental attributes. Someone must therefore maintain this analytic capability on a long term basis. The larger utilities, and NEPOOL, are already capable of this type of analysis, but do not provide a forum for bringing stakeholders together to seek consensus. In this case, MIT, with support from the electric utilities, provided neutral ground whereupon the stakeholders in the regional electricity debate could safely share ideas and brainstorm for solutions. In general, such forums need to be administered by independent entities like MIT, but supported by those stakeholders possessing the strongest analytic and financial resources.

The projects described in this research used an approach for harnessing public participation to evaluate the intangible impacts of planning choices (such as environmental degradation) that contrasted with that used in the technical sessions for externality valuation (MA DPU Order 86-36-F & G/89-239). During the technical sessions, participants were asked to estimate the value of avoiding increments of air pollution. Using secret ballots, they recommended adders ranging from 0.1% to 100% of the current price of electricity. During the next year the parties presented evidence to the DPU justifying adders all across this range, but could not reach a consensus on any value. The DPU was left to weigh the evidence and recommend a (unavoidably controversial) course of action, which they have not yet done even though almost two years have passed since the question was asked. By contrast, the multi-attribute approach used in both the New England and COM/Electric projects avoided this pitfall. All of the parties in the COM/Electric project agreed on the efficacy of two items – increased demand-side management and reserve margin – within the space of three meetings a month apart. Consensus on repowering built noticeably in the New England advisory group between the June and January questionnaires. In these projects the time was spent finding areas of agreement instead of battling over areas of disagreement in public policy.

Advisory group/analysis team interactions within a scenario-based multi-attribute tradeoff analysis framework may thus represent a useful general approach for joint fact-finding. The arrangement can spur the stakeholders' inventiveness and thereby improve the quality of the options being debated. It can help to shift the debate away from arguments over the choice among different options for the next single investment, towards discussion of attractive long range, multi-option strategies. This framework does not reduce the normative content of the analysis, it merely manages it better. The normative steps are more clearly flagged, allowing parties to buy into important parts of the analysis without agreeing on all planning assumptions.

The least valuable part of the New England project was the conflict analysis portion. Its analytic insights lagged rather than preceded the debate in the advisory group. Both projects showed that efforts to understand the detailed preferences of the stakeholders were not very fruitful while the process of inventing better technical options was still going on. Preference elicitation would presumably become more valuable once everyone was convinced that the best possible "efficient set" of strategies had been identified. Whether that threshold could be reached in these projects remains to be seen. The general value of this approach in improving the quality and degree of convergence of the debate was clearly demonstrated; its efficacy in achieving a formal consensus was not.

Uncertainty

When the perception of uncertainty affects a public debate, then its effects must be publicly explored. The experience of both the New England and COM/Electric projects made this assertion axiomatic.

The process of exploring multiple futures for each strategy gave the analysis more credibility and value, but not for the reasons originally postulated. I originally supposed that controversy over what different parties considered to be the most likely set of future events contributed to planning paralysis. However, during these experiments the parties did not want to look at just their personal "high probability" future; instead they wanted to understand the relative robustness of strategies across a wide range of futures. The uncertainty analysis showed that strategies may be robust along one attribute, but not another. The conflict then reduced to one concerning how different parties valued volatility in one attribute versus another. Conflicting preferences among strategies was more due to different attribute prioritizations than to different expectations of the future. By exploring uncertainty, the essence of a debate can thus be made much clearer.

Evaluation across multiple futures also helped the participants to better understand different strategies' strengths and weaknesses, and thereby invent better (i.e., more robust) strategies. This spurred the parties' inventiveness, and helped them choose among strategies having differing levels of robustness in their impacts along specific attributes. By exploring uncertainty, the debate also became much more constructive.

Complexity

The complexity of the New England electric power system had kept public debate on planning options at a simplistic level for years, as opposing parties put forward polarized single-option solutions. By framing our enquiries in terms of multi-option strategies, we freed the participants to explore the mutually beneficial middle ground. Strong analytic support was a prerequisite for this kind of brainstorming.

The participants also discovered the value of crafting carefully coordinated strategies, as opposed to simply horsetrading options into a lowest-common denominator strategy. In these electric power debates, there were significant and counter-intuitive interactions among the options of which the strategies were comprised. By identifying these, analysts can maintain efficiency in a more equitable planning process.

The COM/Electric project demonstrated that a lay audience could provide useful input into a technically complex planning process. Non-expert public participants were able to offer guidance to the professional utility planners regarding important normative decisions. Responsibility for value judgements about the tradeoffs among costs, environmental impacts, and reliability can thus be shared with members of the public.

The utility companies are the best-equipped entities to provide analytic support to their open planning processes because they have technically trained staff and computing resources. Indeed, several utilities are putting together modeling capabilities similar to those recently developed at COM/Electric. NEPOOL also currently maintains this capability, with the exception of environmental attribute modeling, and in the past, the New England Governors' Conference Energy Planning Committee has requested that they study various topics. However, NEPOOL and the individual utilities will not be credible information providers unless they prove the neutrality of their analysis. Initial steps in this process would be to begin to model environmental attributes, share the responsibility for making assumptions, i.e., undertake joint model-building, and become responsive to information requests from non-utility and non-government parties (i.e., environmentalists). While any of these steps could seem to conflict with the short-term strategic business considerations of these investor-owned corporations, the improved stability in the long-term could be well worth it.

NEPOOL suffers from an additional type of vulnerability. Its funding comes from its member utilities, who occasionally indulge in strategic actions towards each other through it. They also sometimes treat it as an unwanted obligation, like government taxes, that deserves mainly to be minimized. Thus some of the analyses undertaken by NEPOOL staff and committees suffer from at least the perception of bias. However, the NEPOOL models themselves, and their assumptions, are accessible to outside groups. Interested parties who make the time commitment to learning the models may run them on their own, and draw their own conclusions about the results. Therefore, even if an entity like MIT needs to execute the analysis to "ensure its neutrality," NEPOOL (or individual utilities) could build the modeling capabilities to make this feasible. In more general terms, planning processes can be opened up even if most of the modeling resources remain in private hands. Access to those resources, support of independent analysts, measurement of multi-attribute impacts, and the ability to run multiple scenarios are keys to that goal.

Tradeoffs must be made between using industry-standard models that only approximate the analytic needs of the project, versus developing new models from scratch. Industry-standard models have the advantages of being known and understood, and of being immediately available, often at a low cost. However, they often are not designed for scenario generation, and may not calculate important attributes. In the New England and COM/Electric projects, we augmented existing models to allow planning under uncertainty, to measure multiple attributes, and to run many scenarios. Entities with longer time horizons and larger budgets than ours, such as the Northwest Power Planning Council (1986) and NEPOOL (NEPLAN, 1989), have constructed their own models from the ground up, allowing more useful features to be implemented. *Ad hoc* joint fact-finding efforts are unlikely to have that luxury.

Neutrality

The credibility of the analysts was crucial to the success of both projects. For the expert audience, they needed to demonstrate both neutrality and technical competence. For the lay audience they needed to demonstrate neutrality and an ability to communicate the normative aspects of technical questions. Comments were repeatedly made – by environmentalists in particular -- that this same analysis would not have been credible if it had been done by the utilities instead of MIT. Yet the MIT team had to earn the right to the neutral's role by overcoming a series of obstacles which are likely to arise in other planning debates. A few a mentioned here; see Nash (1990) for an interesting discussion of others.

First, the stakeholders in the debate have to be convinced that a joint fact-finding effort would be worthwhile. The MIT team had to depend on internal institute resources for support during the first year of the effort. Only after useful results were cost-effectively produced did external donors back the project. In general, parties are unlikely to believe that single-option solutions are inefficient, or that complex systems can have counter-intuitive behavior, or that all-gain solutions can be found, unless it is demonstrated for them. A "seed" project needs to precede the full effort.

Second, people must be differentiated from institutions. The MIT name carries an aura of technical competence but not of neutrality. Indeed, the institution is regarded by some as a "tool of industry" and its official spokesperson, the president, has advocated for one of the single-option solutions in New England's polarized debate – nuclear power. Members of the analysis team hold quite different points of view from the president, but the project participants had to get acquainted with the individual analysts and their work before trust could be established. Both their competence and neutrality had to be demonstrated; only then could they gain personal credibility as neutrals. Institutions cannot advertise neutrality in public disputes; their personnel must earn it. However, institutions can play an important role by improving public access to these individuals (and their time), and by raising the seed money needed to launch dispute resolution efforts.

Third, the composition of the analysis team along several dimensions is important. Technical credibility depends in part upon being able to demonstrate expertise in all of the relevant disciplines, for example, electrical and mechanical engineering, chemistry, regional economics, and applied statistics. Neutrality depends in part upon being able to show a diversity of views within the analysis team. Their biases are more likely to be self-correcting if different analysts have backgrounds in each of, say, conservation, combustion technology, solar energy, and nuclear energy.

Role of the Analyst

The projects described in this research cast the analysts in non-traditional roles. Instead of working invisibly to simply "get the numbers right" we also had important facilitation responsibilities. We developed a consensus-building rather than a consultative mindset. Two illustrations of that follow.

First, during the process of building the models and defining the analytic assumptions on the New England project, we learned that it was always better to share than not to share these responsibilities. Joint assumption making brought adversaries face-to-face and forced them to carefully define their differences. It helped the parties better to understand what was being modeled, which gave them more confidence in the final results. It also provided a quality control check on our own work. In the case where we modeled demand-side programs without consultation, we were not credible, and had to repeat the analysis under the scrutiny of a demand-side subcommittee. Sharing modeling responsibility took time, but was vital for establishing credibility.

Second, the process of narrowing the scope of the analysis required a consensus among the participants. In choosing which two thousand scenarios to model (out of the infinite number of possible scenarios), some options and uncertainties had to be postponed. However, the stakeholders would mistrust any analysis that ignored their primary concerns, thus the scoping effort required a consensus. The job of facilitating the prioritization process belonged to the analysts, and we relied upon discussions, voting, and questionnaires to do this. An important aspect of our work thus consisted of leading a diverse group of opinionated decision makers to a consensus.

The expert audience of the New England project demanded a role in model building and assumption making activities. The procedural challenge there was one of attentive refereeing. The lay audience of the COM/Electric project had to be coaxed into helping to make assumptions and value judgements. The analysts in that case had to serve as translators of technical jargon in addition to managing the normative content of the work. More decision making power was thus concentrated in the analysis team in that case. In general, it is clear that analysts need both process skills and technical skills in order to succeed in this type of work. Some process skills can be learned on the job, but a great deal more can be gained from formal training

A Revised Framework

Based on the lessons learned from the New England and COM/Electric projects, the initial scenario-based multi-attribute tradeoff analysis framework (as outlined in Chapter Four) may be improved. The case studies showed it to be effective in overcoming the barriers of controversy, uncertainty, and complexity, but also identified some weaknesses. The first two steps are relatively unchanged. The third step now includes explicit recognition of the "story" development phase, since it puts so many value judgements in the hands of the analysts. The most significant changes are in the fourth step, where detailed conflict analysis is abandoned since learning effects reduce its value, and suggestions for eliciting participants' preferences during the negotiation process are added, to help with "live" consensus-seeking activities. The revised framework is summarized below, with the changes underlined in Tables 9-1 to 9-5, and annotated on a step-by-step basis in the discussion that follows.

Table 9-1: Open Planning Process Steps (Revised Framework)

1. Identify issues to focus the analysis upon, and attributes by which to compare the performance of different options.
2. Develop scenarios examining the performance of combinations of options (strategies) across a variety of uncertain future events (futures).
3. Explore system behavior by observing the multiple-attribute tradeoffs between strategies, for a variety of possible uncertain future conditions. Develop better strategies based on this information.

Repeat until diminishing returns set in........

4. Seek consensus on a favored strategy. Observe which strategies interest each party, what uncertainties concern them, and how they weigh the various attributes relative to one another. Adjust strategies to increase the potential for consensus based on this information.

Repeat as necessary........

In Table 9-1, Steps Four and Five of the initial framework have been collapsed into a single new Step Four. The analytic effort to understand participants' preferences lagged the debate in the New England and COM/Electric projects, primarily because of the effects of learning on peoples' preferences. Therefore I felt that the detailed information on preferences should be elicited during the directional consensus-seeking process rather than during the expansive inventing process. It is more useful for fine-tuning potentially acceptable strategies than for developing entirely new classes of strategies, which can be done based on simple attribute prioritizations.

Table 9-2: Step One – Identify Issues and Attributes (Revised Framework)

1.a. Define goals driving the project.
1.b. Conduct a stakeholder analysis.
1.c. Solicit participation of a spectrum of stakeholding parties.
1.d. Brainstorm issues and attributes in analysis team prior to first advisory group meeting.
1.e. Elicit issues related to project objectives from participants.
1.f. Cluster the issues with participants.
1.g. Prioritize the issues with participants.
1.h. Identify attributes for measuring progress on issues with participants.

Table 9-3: Step Two – Develop Scenarios (Revised Framework)

2.a. Brainstorm uncertainties and options in analysis team prior to advisory group meeting.
2.b. Brainstorm uncertainties with participants.
2.c. Brainstorm options with participants.
2.d. Develop possible futures by exhaustively combining uncertainty values.
2.e. Develop possible option sets by strategically combining options.
2.f. Develop possible strategies by exhaustively combining option sets.
2.g. Develop possible scenarios by exhaustively combining futures and strategies.
2.h. Prioritize scenarios with participants, postponing some uncertainties and options to later analyses.
2.i. Validate modeling assumptions and techniques with participants.
2.j. Identify information gaps and data needs; fill these with help from participants.
2.k. Analyze the scenarios, and develop a symmetric multi-attribute data set.

Table 9-4: Step Three – Explore System Behavior (Revised Framework)

3.a. Observe the effects of uncertainty.

- i. *Over what ranges do impacts vary?*
- ii. *How relevant are the different uncertainties?*
- iii. *How different are the various futures?*

3.b. Observe the performance of strategies – one attribute at a time.

- i. *How do individual options perform along various attributes?*
- ii. *How does each option set perform along various attributes?*
- iii. *How consistent is the performance of each option set?*
- iv. *How does each strategy perform along various attributes?*
- v. *How do the strategies rank relative to one another?*
- vi. *How consistent are strategy rankings across different futures?*
- vii. *How volatile is the performance of each strategy given uncertainty?*
- viii. *Do different uncertainties affect different strategies?*

3.c. Observe the performance of strategies – consider multiple attributes.

- i. *How does each strategy perform for different attribute pairings?*
- ii. *How consistent is the performance of each strategy across various possible futures?*
- iii. *How does each strategy perform considering all attributes?*

3.d. Observe the performance of the system.

- i. *Do different attributes correlate with one another?*
- ii. *Do some attributes explain others?*

3.e. Share the above information with the participants in the form of "stories."

- i. *Establish that a widely believed phenomenon is true in this case?*
- ii. *Show convincingly that a counter-intuitive result makes sense?*

3.f. Invent better strategies and explore more relevant uncertainties.

- i. *Based on what we have learned about the system's behavior, which additional strategies need to be evaluated?*
- ii. *Are there other uncertainties to consider?*

Repeat steps 1 to 3 above until diminishing returns set in.....

Table 9-5: Step Four – Seek Consensus (Revised Framework)

4.a. Sort through the strategies – slowly add normative content to the decision rules.

- i. *Which strategies are dominated by others across all attributes and futures?*
- ii. *Which strategies are dominated by others across all attributes, if equal probabilities are assigned are assigned to all futures?*
- iii. *Assuming risk-aversion, how does the decision set change?*
- iv. *Emphasizing different futures, how does the decision set change?*
- v. *Emphasizing different attributes, how does the decision set change?*

4.b. Understand stakeholder values.

- i. *How do different parties prioritize attributes?*
- ii. *How do different parties view uncertainty?*
- iii. *How do different parties view the various strategies?*

4.c. Revise the strategies.

- i. *Are there new packages of options that have more of the characteristics everyone prefers?*
- ii. *What new strategies have the potential for consensus?*

4.d. Seek consensus.

- i. *Vote for preferred strategies, in order of increasing cost.*
- ii. *Where are the thresholds, non-linearities in individual preferences, areas of gap or overlap?*
- iii. *Use "synonym attributes" to help participants understand the implications of their choices.*
- iv. *Identify a consensus strategy (or component of strategy).*
- v. *Confirm that a consensus was reached by asking each participant to sign off on the result.*

Repeat steps 1 to 4 above if necessary.....

Step 3.e. in Table 9-4 was added in order to focus attention on an activity that was forced upon us by the practical constraints of our approach. The generation of thousands of scenarios using assumptions agreed upon by consensus, accounting for uncertainty by covering ranges, and measuring multiple attributes to avoid valuation problems, provided too large a data set to be directly shared with the public. The data had to be boiled down to a few defensible "stories" that could be simply explained. The inductive data analysis thus gained some guiding objectives: Can it be established that a widely believed phenomenon is true in this case? Can we show convincingly that a counter-intuitive result makes sense? Mining the data for such stories, and then documenting them for public presentation became vital steps in the process of exploring system behavior. The revised table recognizes this.

The revised last line in Table 9-4: "Repeat Steps 1 to 3 above <u>until diminishing returns set in</u>..." reflects experience gained in the two projects. When efforts at preference elicitation were made while the participants were still exploring system behavior, they were not fruitful. This suggests that the participants should stick with Step Three until the range of possible strategies has been adequately mapped out, and only then move to consensus seeking in Step Four.

In revision, Step 4.b. of Table 9-5 was changed from "elicit" to "understand" stakeholder values. This reflects a change in the planned use of that information Instead of providing a basis for modeling stakeholder preferences and thereby conducting a detailed conflict analysis, the information on preferences will serve a more informal purpose. Preference information will help to guide the discussion rather than map out new negotiating areas. The preference information will determine the ordering of the tradeoff graphics, and which combinations of bivariate data to present.

The conflict analysis step was deleted in the revised Step Four shown in Table 9-5. As was discussed earlier, in its current mode of application it lags rather than leads the discussion of tradeoffs. However, it represents an area that could substantially benefit from further research.

Step 4.c. of Table 9-5 changed from "invent" to "revise" strategies. This reflects the view, evolving from these case studies, that Step Three needs to be repeated until diminishing returns set in. If more of the strategy possibility space is filled in during Step Three, then Step Four will focus mainly on interpolating between strategies to find those with the potential for consensus.

Step 4.d. of Table 9-5 collapses the old Step Five in with activities that were previously included in conflict analysis. In the revised framework, a series of facilitation steps (rather than analysis steps) are offered to help the analysis team support the advisory group in seeking consensus. These steps were discussed in more detail in Chapter Eight, and represent my view of: (1) the type of information that will be useful to the participants in understanding their own preferences, (2) questions that will reveal to the participants whether and where there is negotiating room, and (3) how to test whether a stable consensus has been reached.

Recommendations for Future Research

Since both the New England and COM/Electric projects are continuing, this revised framework has immediate applied relevance. The lessons learned to date can be put to use improving the efficacy of these projects. In particular, the projects should continue in their quest of acceptably complete "efficient sets" of strategies and, once found, test whether consensus can be achieved.

The potential for using tradeoff analysis to determine the public's marginal rate of substitution between dollars and environmental impacts is also worth exploring. This approach to setting shadow prices for environmental externalities is theoretically acceptable, but needs to be proven in practice. An especially important aspect to consider is the consistency of the results across individuals and planning contexts – are these shadow prices too context-specific?

The preference elicitation step in tradeoff analysis needs further thought. While scatter plots with tradeoff frontiers were extremely useful when there were only two attributes, our matrix-based attempts to characterize the performance of strategies along eight attributes were not. Tactics to ensure that all eight attributes are considered need development. Further consideration of utility functions may be appropriate to force the participants to become coherent and consistent in their preferences. Computer-based tradeoff models such as that produced by Rowley (1989) could quite efficiently elicit decision makers' preferences. Ways to incorporate wider public participation, through survey instruments, for example, should also be explored.

The analysis team injects normative content into the analysis by having the responsibility of wading through the data on behalf of the advisory group to identify "stories." One way to avoid potential biases resulting from this activity would be to make the data set more directly accessible to the stakeholders. Hypercard indexing or other interactive computer techniques could make the data accessible in a user-friendly manner to anyone with a personal computer. This would "take out the middleman" and let the participants mine the data themselves. While the decision makers in the New England advisory group would be unlikely to take advantage of this because of the required time investment, their technical staffs and members of the public might be quite interested in such a prospect. This would require implementing process steps three and four in an interactive computer display.

While computing power to run scenarios is getting cheaper and more available, the time required by the analysts to prepare the input data and then understand the output remains significant. The data analysis strategies presented here help to manage the output of thousands of scenarios. However, the input data stage could also benefit from careful thought. Would short-cut techniques such as Latin Hypercube sampling (Grubb, 1988) allow bracketing of uncertainties in an accurate way given the important interactive effects occurring in some complex systems? Would such techniques change the value of the results in a consensus-building context?

There are likely to be contextual dimensions determining the usefulness of the scenario-based multi-attribute tradeoff analysis approach. For example, this research explored whether the expertise of the participants affected the efficacy of the approach. Other factors could also be explored, such as the level of polarization of the different parties in a debate, and the degree to which the planning debate may be re-cast in terms of multi-option strategies instead of single, lumpy options.

A final area of research suggested by the work to date is in the area of multi-attribute optimization under uncertainty. The electric power industry in particular needs to develop better methods of this type to support truly integrated resource planning. Demand- and supply-side options, both investment and operational, need to be coordinated within planning portfolios to balance potentially conflicting goals of cost minimization, environmental impacts reduction, and reliability maintenance. Many of these tasks do not relate to the consensus-building motive driving the current research. Instead they are efficiency-driven. System-wide multi-attribute optimization is needed to answer such questions as: "what does the supply curve for sulfur dioxide reductions in New England's electric power system look like; what is the least-cost, yet robust, multi-option strategy to achieve a certain level of emissions reductions?"

Conclusions

These experiments with opening up technically complex planning processes had many successful aspects. They demonstrated that meaningful public participation in major project planning was feasible, and that a consensus-seeking stakeholder group enjoying appropriate analytic support could induce progress in a deadlocked policy debate.

The efficacy of the scenario-based multi-attribute tradeoff analysis technique was also demonstrated. It reduced controversy over modeling assumptions, revealed the performance of a wide variety of options across a large range of uncertainties, highlighted the importance of developing coordinated strategies out of many individual options, and showed tradeoffs along multiple attributes. The value of symmetric scenario set construction was verified during inductive data analysis – it simplified the process of developing convincing "stories" and postponed the need to make certain value judgements until later stages of analysis.

The results of these experiments are likely to be of primary interest to electric power planners, but they may also provide useful insights for other planning contexts. Large infrastructure investments of many types face the threat of policy paralysis due to a lack of consensus resulting from controversy, uncertainty, and complexity. Water, sewage, and transportation systems are obvious examples. International environmental debates, such as those about acid deposition, greenhouse gasses and stratospheric ozone depletion, may also need to undertake similar consensus-building modeling activities and evaluate multi-faceted policy responses.

The ways that technology-dominated decisions are made in democratic societies need to be improved. The affordable margin for error has decreased as the mass of humanity, its power to alter the physical environment, and its material expectations have all grown, while the carrying capacity of the world has not. The voices of many parties need to be heard in planning processes that affect those parties, yet valued expertise should not be supplanted. Consensus planning is desirable, but lowest common denominator planning is not. This research has explored one path for balancing public participation and technical expertise. It has demonstrated that creative thinking is encouraged by opening up a planning debate, while also providing suitable analytic support. That outcome should spur further experiments by others.

APPENDIX A1:
PARTICIPANTS' LIST FOR THE NEGOTIATED LEAST-COST PLANNING SIMULATION

PARTICIPANTS IN THE INSTITUTE ON REGULATORY REFORM MIT-HARVARD PUBLIC DISPUTES PROGRAM, NOVEMBER 1989

Chairman
Alberta Public Utilities Board

Director, Technical Services
Alberta Public Utilities Board

Chairman
Arizona Corporation Commission

Vice President, Finance & Rates
Arizona Public Service Company

Senior Vice President
Arkansas Power & Light Company

Commissioner
British Columbia Utilities Commission

Vice President & Legal Counsel
Boston Edison Company

Senior Vice President
Boston Edison Company

Vice President
Boston Edison Company

Vice President, Corporate Sales &
General Counsel
Canadian Utilities Limited

Associate General Counsel
Carolina Power & Light Company

Corporate Counsel
Central Vermont Public Service Co.

Attorney
Cincinnati Gas & Electric Company

Assistant Manager
Cincinnati Gas & Electric Company

Commissioner
Colorado Public Utilities Commission

Counsel
Distr. of Columbia Off. Peoples' Counsel

1st Deputy Counsel
Distr. of Columbia Off. Peoples' Counsel

2nd Deputy Counsel
Distr. of Columbia Off. Peoples' Counsel

General Manager, Marketing
Delmarva Power & Light Company

Associate General Counsel
Duke Power Company

Vice President, Law & Corp. Affairs
Duquesne Light Company

Manager, Utilities Services
General Motors Corporation

Executive Director
Hawaii Division of Consumer Advocacy

Attorney-at-Law
Iowa Office of Consumer Advocate

Manager, Rate Department
Attorney
Idaho Power Company

Deputy Attorney General
Idaho Public Utilities Commission

Senior Assistant Attorney General
Illinois Office of Attorney General

Executive Director
Illinois Commerce Commission

General Counsel
Illinois Commerce Commission

Chief Auditor
Illinois Commerce Commission

Manager, Rates
Illinois Power Company

General Counsel
Kansas City Power & Light Co.

Group Vice President
Kansas Gas & Electric Company

Chairman
Kentucky Public Service Commission

Vice President, Rates & Forecasts
Kentucky Utilities Company

Director
Kentucky Office of Attorney General

Vice President Public & Gov't Affairs
Maine Yankee

Chairperson
Massachusetts Dept. of Public Utilities

PARTICIPANTS IN THE INSTITUTE ON REGULATORY REFORM MIT-HARVARD PUBLIC DISPUTES PROGRAM, NOV. 1989, CONT'D

Director, Rates & Research
Massachusetts Dept. of Public Utilities

Director, Electric Power Division
Massachusetts Dept. of Public Utilities

Assistant Director, Electric Power Division
Massachusetts Dept. of Public Utilities

Director
Michigan Public Service Commission

Advisory Board Member
MIT/Harvard Public Disputes Program

Vice President, Regulatory Affairs
Montana-Dakota Utilities Company

Vice President, Regulatory Affairs
Montana Power Company

Commissioner
Montana Public Service Commission

Vice President & Director of Rates
New England Electric System

Commissioner
New Hampshire Public Utilities Comm.

Administrative Law Judge
New York Public Service Commission

Vice President, Economics
New York State Electric & Gas Co.

Attorney
North Carolina Utilities Commission

Director, Revenue Requirements
Northeast Utilities Company

Consumer Advocate
Nevada Office of Attorney General

Legal Director
Ohio Office of Consumers' Counsel

Assistant Attorney General
Oregon Department of Justice

Assistant Commissioner, Hearings Div.
Oregon Public Utilities Commission

Manager, Rates Department
Pacific Gas & Electric Company

Consumer Advocate
Pennsylvania Off. of Consumer Advocate

Vice President, Rates & Cust. Programs
Puget Sound Power & Light Company

President
Quebec Gas Board

Group Manager, Rates & Regulation
Southwestern Public Service Company

Attorney
Steer, Strauss, White & Tobias

President & Chief Executive Officer
Transalta Utilities

Assistant General Counsel
United States Department of Energy

Chairperson
Washington Utilities & Trp. Commission

APPENDIX A2:
TEXT OF THE NEGOTIATED LEAST-COST PLANNING SIMULATION

LEAST-COST PLANNING EXERCISE

General Information For All Parties

Background:

The "bubble" of excess generating capacity that existed during the mid-1980s at GENCO, the electric company, has now dissipated. The capacity reserve margin has dropped from nearly 40% to a mere 20% above peak load, becoming uncomfortably close to the minimum level necessary to maintain adequate service reliability. With unexpectedly high demand growth in recent years, a result of both weather and economic trends, the utility sees a need to move quickly to meet the growing demand for electricity. Otherwise, potentially devastating power outages may occur. Reliability problems induced by an electricity shortfall would have significant social costs.

The problem is becoming clearly defined: there is a looming imbalance between the availability of and demand for electricity. There is a broad menu of solutions that includes conservation/demand-side management, gas- and oil-fired generation, and coal-fired power plants, provided either by the utility or independent power producers. Each stakeholder in the debate has a favored solution. Because of the right to intervene in regulatory hearings, each of them also has some degree of power over the outcome of the planning process. How can progress be made in the face of massive controversy and uncertainty?

Five parties plus a mediator, which include representatives of the electric company (GENCO), a consumer group (NOPE), the Public Utility Commission, an environmental group (CLEAN), an independent power producer (IPP), and the mediator (Professor Calme), attended an initial meeting last month that succeeded in focusing the discussion on a limited set of indivisible planning options that are on the table today. All of the parties have researched the issues in greater depth. Today, the group will attempt to reach consensus on a project proposal--one that all stakeholders would be willing to sign off on.

In the approximately one hour meeting in which you are about to participate, the goal will be to formulate a consensus least-cost plan for submission to the Public Utilities Commission. The Chairman of the state PUC has announced that if a consensus document is submitted, then pre-approval of all project expenditures recommended therein will almost certainly be granted. This would allow the electric company to move quickly to meet the demand for electricity. If the mediator cannot get the five participants to put their signatures on a plan, then the project must pass through the full regulatory process, a time-consuming, expensive, unwelcome prospect for all involved.

Professor Calme, a respected member of the electrical engineering faculty at Hi-Tech University, has been asked by the electric company to help with this situation. Nearing retirement, and glad to get away from the drudgery of National Academy of Engineering committee work, the professor has offered to serve as a mediator and chief fact-finder for a joint planning effort. The goal will be to take an open and "public" look at the options available to the electric company, and to develop the outlines of a least-cost

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This simulation was created by Clinton Andrews under the supervision of Lavinia Hall for the M.I.T.-Harvard Public Disputes Programs. Copies may be obtained at reasonable cost from the Program on Negotiation Harvard Law School, Cambridge, MA 02138, (617) 495-1684.

planning strategy to be detailed in the company's next submission to the PUC, due tomorrow.

The issues that you need to try to reach consensus on are:

1) The best way to meet the increased demand for electricity that is expected;
2) How to calculate the costs of environmental and social issues associated with whichever option is chosen to meet the electricity demand;
3) Whether the option chosen is to be implemented by the IPP or GENCO;
4) Any additional contingencies relative to 1 - 3 above that are needed in order to achieve consensus;

Memories of the costly excess-capacity situation linger in both the company planning department and the regulatory arena. Much of this excess was the result of the start-up of a single large nuclear plant, one that took fifteen years to build, caused rates to jump, and attracted a Public Utility Commission (PUC) prudency review leading to one third of the construction cost being disallowed from the rate base. Based on this debacle, the utility is reluctant to make another major investment in new capacity unless it can reduce the uncertainty surrounding cost recovery. The required level of capital commitment profoundly affects the utility's preferences among project options.

None of the regulators appears interested in large new power plants either. Following the lead of the federal government's Public Utility Regulatory Policies Act (PURPA), the state PUC is seeking to promote competition in the electric power industry by allowing power production by third parties. These independent power producers finance and build their own plants, and sell most of their output to the utility. It is hoped, but currently uncertain, that such competition will keep electricity generation prices down without adversely affecting the quality and reliability of supply. One of the decisions which must be made today is whether the utility or the independent power producer should make the next capacity investment. Regarding costs, remember that a high first-cost/high-efficiency plant that minimizes fuel price-related risks could have the same ¢/kWh as a low first-cost/low-efficiency plant that minimizes capital-related risks. These relative risks must somehow be weighed in the least-cost planning process.

The Parties:

- President, Generic Electric of New England (GENCO)
- Spokesperson, Neighbors Outraged at the Price of Electricity (NOPE)
- Director of Electric Power Planning, State Public Utility Commission (PUC)
- Senior Attorney, Clean Air Now!, Inc. (CLEAN!)
- President, Independent Power Production, Inc. (IPP)
- Professor Calme, Hi-Tech University (Mediator)

GENCO -- must hold shareholders' interests primary and run a profitable venture -- cost recovery is a major goal. However, it also must take seriously its obligation to serve. Like other business leaders, it sees a strong coupling between electricity availability and economic growth. It does not want shortages to throttle the recent expansion of economic activity in the region.

NOPE -- Neighbors Outraged at the Price of Electricity represents the consumers. Its main concern is cost, but social costs will be calculated too. NOPE's focus on the electric power industry is on the volatility of electric rates. Under the influences of the oil price shocks and the nuclear power plant construction cost overrun, the real price of electricity has dramatically increased in recent decades. "Least-cost planning" must be heeded in both the utility boardroom and at the regulators' offices. The least-cost planning philosophy is firmly embedded in both the regulatory structure and the utility planning mechanism at this point. The technology with the lowest life-cycle cost (i.e., construction and operating costs including fuel, levelized over project life, in ¢/kWh) is the option that should be selected.

Public Utilities Commission -- will play a pivotal role in the negotiations, no doubt. PUC commissioners may run the gamut in interests and priorities, from making the electric industry more competitive to conservation and load management strategies. Their views on the social costs of pollution will also be heard.

CLEAN -- Clean Air Now wants to eliminate or at least reduce the environmental problems caused by the electric utilities industry. Electricity production contributes to global warming, acid rain, smog, hazardous waste generation, and site-specific impacts. Federal regulations regarding plant emissions are becoming much stricter but are not strict enough. The connection between continued expansion of electricity generating capacity and major pollution problems is painfully clear. CLEAN will intervene in every rate and siting hearing connected with new power plants. Investments in efficiency and energy conservation are the best ways to meet the growing electric demand in CLEAN's view.

IPP -- Independent Power Production has a great interest in helping the state to create a truly competitive power market. It has voiced skepticism about whether the PUC is really serious about this idea.

Good luck in your negotiations. Remember, your goal is consensus on the three issues outlined above. Your confidential instructions will tell you more about your own particular concerns.

APPENDIX: Technical Information Provided by GENCO

Based on the company's official load forecast (which received consensus approval at the last meeting) and the planned retirement schedule for old power plants, it appears that 400 megawatts of additional capacity are needed on-line by 1995 to maintain an adequate reserve margin. Both cogeneration and self-generation have already been netted out of the load forecast. Details about the discrete supply- and demand-side options for maintaining an adequate reserve margin are shown below:

Technology Type	Unit Size (Minimum MW)	Fuel	Levelized Cost (¢/kWh)
Life Extension of unit scheduled for retirement	400	Oil#6	4
Gas Turbine Combined-Cycle	400	Natural Gas (Oil#2 emerg.backup)	4
Atmospheric Fluidized Bed	400	Coal	3
Peak Load Management	200*	(Interruptible Load Cooperatives)	4
(and)			
Conservation	200*	(Lighting/HVAC Subsidies)	4
Total C & LM	400		

* maximum estimated technical potential

Any of these options may be built by either the utility or an independent power producer, except life-extension, which is only available to the utility. If the independent power producer is granted the right to build the next increment of capacity, it is legally guaranteed a long term power sales contract with the utility, under a recent PUC ruling (a similar guarantee applies to their conservation and load management investments). If a consensus plan is submitted, then all technologies are assumed to have the same lead time, because permitting and licensing are likely to be expedited.

Note that no nuclear option is shown. Based on projected load growth and the electric company's recent unsatisfactory experience with bringing a nuclear plant on-line, that option has been temporarily withdrawn from the menu. Additional power purchases from outside the utility's service area also are not feasible because of both local tie-line constraints and regional network flow problems. The participants believe that other emerging technologies such as phased coal-gasification combined-cycle plants are not fully mature, and should not be considered within the current planning period. Similarly, phased construction of a gas turbine combined-cycle was also ruled out at the last meeting; either the entire plant gets built or a different option gets chosen. NOTE: The ONLY technological choices available for use by either the utility or independent power producers are those listed above. Note that ONLY the fuels listed are available at those plant sites; thus no other fuel/technology combinations are possible.

LEAST-COST PLANNING EXERCISE

AGREEMENT

Group # ________________

Consensus reached on:

1) The best way to meet the increased demand for electricity that is expected --

2) How to calculate the environmental and social impacts associated with whichever option is chosen to meet the electricity demand --

3) Whether the option chosen is to be implemented by the IPP or GENCO --

4) Any additional contingencies relative to 1 - 3 above that are agreed to in order to achieve consensus --

(If no consensus is reached, please note where your group stands on the issues above at the conclusion of this session)

LEAST-COST PLANNING EXERCISE

Confidential Advice to the President of GENCO, the Electric Company

Your shareholders are going to cashier you if you can't get the Public Utilities Commission (PUC) to grant a fair rate of return on all of the company's future capital investments. Neither they nor the bond rating service have forgotten what happened to the nuclear power plant investment. In fact, at this point, it would be better to let the lights go out a few times than to make investments that might not be eligible for future cost recovery in the rate base. Your Board of Directors recently voted to cap new capacity expenditures at the $250 million level for this planning cycle. Any amount greater than that would unacceptably skew the company's debt interest coverage ratio.

Since fuel and operating costs are passed through to the customers, only the capital expenditures are really important to your bottom line. Inefficient plants burning high-cost fuel are perfectly tolerable, if they obviate the need for risky investments (plant efficiencies are shown below, and your system average is 34%).

Of the three supply-side options shown in the general information sheet, their initial capital costs (listed below) reveal their relative riskiness: life extension is the lowest risk, combined-cycles are next, and AFB coal is the worst (in fact, unacceptable, following the Board vote). Therefore, those are your preferred options, in order of priority.

Technology Type	Combustion Efficiency	Initial Cost (MM$)
Life Extension of unit to be retired	24%	40
Gas Turbine Combined-Cycle	42%	240
<<Atmospheric Fluidized Bed	37%	760>>

A couple of new headaches must be faced in today's planning session. First, the competition, i.e., the independent power producer (IPP) spawned by PURPA, will try to snap up your opportunity to make a low-risk power plant investment. The regulators are going out of their way to make it easy for this outsider to usurp your role as the builder of local power plants. If IPP is allowed to build the increment of new capacity, then you will be forced by the recent PUC ruling to sign a long-term power purchase agreement with them. In the long run, as old plants are retired, your rate base will shrink into nothing if you can't continue to invest. Although you can certainly accept a few IPP-owned plants of the 400 MW size over the next decade, don't make their lives too easy. Use them to absorb risks you are unwilling to take.

While IPP could shift investment risk away from the utility, it is not at all clear that they would ensure adequate generating capacity. You know that independent power producers have a greater than 50% failure rate; that is, less than half of the independent projects filed ever get finished. The remainder fail to get site permits, lose their financing, or find that changing fuel prices render their long-term fuel supply contracts unpalatable or unobtainable [unlike the utility, which can pass fuel prices through to the customers; and isn't much affected by such fluctuations except as they influence load growth]. Of course, you could reduce IPP's fuel-side risks by including a fuel-price escalator in their power purchase contract. Don't do that unless you are assured of PUC approval to pass those risks on to your ratepayers. Your bottom line regarding IPP is that you should not let them build any new capacity unless your life extension option is completely foreclosed.

The second of today's headaches will arrive courtesy of the environmental coalition. They have testified against every supply proposal the company has made during the last ten years, and played a significant role in creating the costly delays that weakened the economics of the nuclear plant. They are now clamoring to have the definition of "least-cost" planning changed to "least social-cost" planning, which includes the dollar values of pollution impacts. How they hope to quantify and value these impacts is unclear to you. Your economists have reviewed the literature on environmental externalities and reported that there is no consensus on even the order of magnitude of these costs. The highest well-documented number that they saw was 0.1 ¢/kWh for fossil-fueled plants.

Recently the environmentalists have jumped on the conservation bandwagon, claiming that the utility should invest in "negawatts" of conservation just as it does in megawatts of new capacity. They pay no attention to the fact that water heater wraps and light bulbs aren't bondable, which makes financing difficult to get. Besides, the customers themselves are capable of making conservation investments in response to price signals in the energy marketplace; why should the utility offer subsidies to encourage people to do what is in their own best interest? You will want to keep utility-sponsored conservation out of the plan at all costs. It is capital-intensive, at $260 million for 200 MW, and unsecurable. If it must happen, let the independent power producers take on this responsibility -- it is precisely the type of risky investment you would rather relegate to them.

Peak load management via contracts with interruptible load cooperatives is the other demand-side option, and it is marginally more tolerable to you. The initial cost of installing meters and communications hardware is only about $60 million for 200 MW, so that much less utility capital is at-risk. Further, you enjoyed success with a small pilot program last year that bolsters your confidence in this demand-side option. However, remember that your shareholders are less familiar with demand-side (than supply-side) investments, that your engineers know about power generation not weatherstripping, and that the economic health of the region depends on an unencumbered supply of electricity.

Getting an agreement is the most important thing that needs to happen today. Of course, it would be best if the option chosen was life extension. You would also be willing to invest utility funds in the gas turbine combined-cycle plant or in peak load management. You are willing to tolerate IPP investments in either AFB coal or conservation, but you can't invest in those options yourself. Finally, as a last resort, you would be willing to accept a gas turbine combined-cycle plant built by the IPP. You are open to any contingencies or ideas that will make an agreement work. You understand that other parties feel strongly about some other issues that aren't of chief concern to you and you will try to accommodate them.

LEAST-COST PLANNING EXERCISE

Confidential Advice to the Spokesperson for Neighbors Outraged at the Price of Electricity (NOPE)

You represent the single most important group at this meeting. Your constituents consume the electricity, pay the bills, and live next door to the power plants that GENCO owns. Your people pay the taxes that cover the regulators' salaries, and contribute to the environmental organization and university employing others at this table. However, the people you represent are ordinary individuals who are not experts in the field of electric power planning, nor are you, for that matter. You and they want good decisions to be made on your behalf by the so-called experts, and you are here today to make sure that this happens.

The top priority item on your agenda is the cost of electricity. Your poor and elderly constituents have suffered terrible financial hardships just to keep warm during winter and cool during the summer, ever since GENCO's nuclear power plant came on line. Even before that, it seemed that volatile oil prices were passed right through to you and other customers. It appears that GENCO makes a profit no matter what it does, and that the PUC allows it to shift all of its risks onto the shoulders of consumers like you. This is unfair and you need to let the group know this.

You realize that the price of electricity has both a capital cost and an operating cost component, and that different technologies vary along a spectrum from capital-intensive to fuel-intensive. An AFB coal plant, for instance, is extremely capital-intensive, and is estimated (by an engineer you consulted) to cost $760 million if built by GENCO, and about $600 million if built by IPP. However, since it burns cheap, plentiful, and domestically available coal, its operating costs are extremely low, resulting in a very low levelized cost (in ¢/kWh). By contrast, the life extension option would reportedly cost GENCO only $40 million, but it has a poor combustion efficiency and burns oil, which is a relatively expensive fuel that may need to be imported; thus its levelized lifecycle cost in ¢/kWh is not particularly low. Even worse, its costs could be expected to be volatile, if the price of oil bounces around as much in the coming decade as it did in the 1970s and early 1980s.

Ideally, the group should choose a low capital-cost/high-efficiency technology that mitigates both capital- and fuel-side cost risks. However, under the current regulations, you know that GENCO bears none of the fuel-side risks (they are passed on to you) but it does bear some of the capital risks. Therefore, you want to push for options such as AFB coal, and possibly the gas turbine combined-cycle plant, that appear to have lower fuel-side risk exposure.

The second issue that you want to address at this meeting is the concept of "least social cost" planning, which is a variant of the least-cost planning approach. Both the environmental group CLEAN! and the PUC have publicly supported the notion that the social costs of pollution (i.e., the damages to society ranging from loss of fish on mountain lakes, to forest die-off, to increased lung disease, to deterioration of historic buildings and monuments) should be included when selecting which option to build. For you, this issue is something of a double-edged sword: most of your constituents support efforts to improve the environment, but at the same time they don't want the price of electricity to rise as a result. Thus, you will want to inject a voice of reason into the least-cost planning process. Don't let them saddle the options with such high social costs that the actual costs faced by the ratepayers will significantly increase. Be sure that reasonable weight is given to serious pollutant impacts, but don't let the process get tilted to exclusively favor options with much higher actual out-of-pocket costs. The maximum social cost "adder" that you are willing to tolerate is one of about 25%, or 1 ¢/kWh for most options.

The final concern that you have about today's meeting relates to siting issues. At the last NOPE meeting, members living near the proposed sites of the AFB coal and GTCC plants complained that they might have to become neighbors to unsightly, noisy, polluting facilities that would increase local traffic and induce a variety of other undesirable site impacts. It appears to you that the life-extension, load management and conservation options won't impose adverse site impacts, while AFB coal and GTCC will. If any social cost adders are going to be placed on options, you want to make sure that one of them deals with site-related impacts. You doubt that it should be more than about 0.1 ¢/kWh, but the problem should be recognized.

In summary, you are less option-oriented than issue-oriented. You want the least-cost planning process to live up to its name, and select a low lifecycle cost option with low uncertainty surrounding future costs (i.e., low fuel-side risks). You want social costs to be accounted for, but within reason, and you want site-related impacts to be included. Based on the prices included in the general instructions, and what you know about GENCO's and IPP's construction costs, your current preferences are as follows. AFB Coal built by IPP seems to be the best bet, even including a 0.1 ¢/kWh site impact adder. Conservation and peak load management, whether by the utility or IPP, seem to be your next choice. You don't know very much about the GTCC option, but it seems to be on a par with life-extension as one of your lowest priority choices.

LEAST-COST PLANNING EXERCISE

Confidential Advice to the Director of Electric Power Planning at the State Public Utility Commission (PUC)

You are in a rather awkward position in this negotiation, because you are "unofficially" representing your bosses, the PUC commissioners, who cannot communicate directly with parties involved in matters that will come before them as commissioners. You have to convey your impression of how the Commission is likely to rule on a particular issue without being able to guarantee that outcome to the other parties.

Based on recent rulings, and long discussions during staff meetings, you know that the Chairman of the Commission is very interested in increasing the competitiveness of electricity generation; he wants independent power producers (IPP) to have a big share of the future pie – indeed, he wants them to construct all of the new generating capacity for next five or six years. He has worked hard to break down the barriers to entry that have been thrown up by the utility, such as unfavorable power purchase contract terms. If he can find any reasonable grounds for preventing utility investments in supply-side projects, he will use it. You need to encourage IPP activity by recommending flexible terms (such as a fuel cost-related price escalation clause) in contracts governing power sales by IPP to GENCO. Try to make sure that only the IPP gets to build supply-side projects during this planning cycle.

The commissioners are aware of the utility's unwillingness to risk investing in capital-intensive projects given the outcome of the nuclear plant's prudency review. That is one reason why they have offered such a strong incentive to this group to reach a consensus. The IPP offers the utility a way out of its finance problems, as does the recent PUC decision to allow conservation and load management costs to be either passed through as an operating expense (like fuel) or included in the rate base like a power plant.

You also know that the other two commissioners are especially interested in providing a "level playing field" for Conservation and Load Management (C & LM), and wants the utility to include those technologies in its planning process. At this point in time, the conservation option seems to be a surer demand-side bet than the peak load management option. The estimate of conservation's technical potential provided by GENCO seems realistic (perhaps even pessimistic), and there are clear pollution-reduction advantages that accompany that strategy.

However, you remain skeptical of the technical potential of the load management option chosen, that of interruptible load cooperatives. The certainty with which the load management technical potential figures were reported by the utility seems optimistic to you. Data provided in a recent state Energy Office study suggest that the estimate shown in the general information sheet is highly-uncertain: it should read 200 ± 100 MW.

This technical potential number is important to you because if the utility chooses a demand-side strategy that turns out not to meet predicted resource needs in 1995, then severe reliability problems are likely to result. A shortfall in electricity supply relative to its demand would be very costly to the economy of the area. A Chamber of Commerce study recently estimated that several seasons of shortfalls would impose social costs (lost production, lost sales, equipment damage) equivalent to a 1 ¢/kWh increase in the cost of electricity. You believe that the load management option should be assigned a "risk premium" to account for the uncertainty surrounding its estimated technical potential. A handicap of 1 ¢/kWh gives the option a revised social cost of 4 + 1 = 5 ¢/kWh.

It is also your responsibility in this meeting to be alert regarding environmental matters. You need to push the utility to negotiate seriously with the environmental organization (CLEAN!) now, so that the next round of hearings don't get bogged down in adversarial interventions.

The EPA in Washington has prepared estimates of the "social" costs of electricity production, based on impacts from airborne pollutants. These are outlined in the table below, which shows the dollar values of pollution damage likely to result from specific quantities of sulfur (di)oxide(s) and nitrogen oxides (NOx), emitted from the smokestack. The state-of-the-art in modeling of pollutant transport, fate, deposition, and impact on property, plants and animals still produces highly uncertain results. However, the results still indicate significant adverse impacts that should be considered in evaluating projects. While the commissioners have not formally broadened the definition of least-cost planning to include social costs, they are about to do so. You should recommend to the group that they choose the "least societal-cost" option.

Technology Type	Pollutant	Lbs/1000 kWh x	¢/Lb	=	¢/kWh Impact
Life Extension	SOx	15	5	=	00.08
burning Oil #6	NOx	6	50	=	0.3
					0.38 ¢/kWh
GT Combined Cycle	SOx	0	5	=	0
burning Nat. Gas	NOx	2	50	=	0.1
					0.1 ¢/kWh
Atmos Fluidized Bed	SOx	11	5	=	0.05
burning Bitumin. coal	NOx	8	50	=	0.4
					0.45 ¢/kWh

Conservation and Load Management have zero pollution impacts.

Your summary of adjustments to the cost of electricity to reflect risk and environmental impacts follows:

Technology Type	Current Levelized Cost (¢/kWh) +	Adjustment	= Total (¢/kWh)
Life Extension of unit to be retired	4	+0.4	= 4.4
Gas Turbine Combined-Cycle	4	+0.1	= 4.1
Atmospheric Fluidized Bed	3	+0.5	= 3.5
Peak Load Management	4	+1+0	= 5*
Conservation	4	+0	= 4*

* At 200 MW each the average cost of C & LM is 4.5 ¢/kWh.

Use these numbers for prioritizing the options, because they have been adjusted to account for the factors of greatest concern to you. Try to convince the rest of the group that this ranking of the options deserves their support. Get them to air their differences on perceived social costs as a way of finding the least-cost option. Controversial rulings give the PUC much worse press than consensus rulings, so work to include everyone. However, don't forget that the Commission's primary mission is broader than the environmental issue, it is to ensure that the public is provided with sufficient, reliable, least-cost electricity.

In summary, you prefer to see IPP granted the right to build whatever is identified as the least-cost supply option. Your information above suggests that AFB coal is cheapest, followed by GTCC and then life-extension. If the conservation and load management package becomes the option of choice, then you are indifferent about whether it is implemented by GENCO or IPP, or both. The most important thing is to get an agreement, one that everyone recognizes as being least-cost.; you will accommodate others so long as your needs are met.

LEAST-COST PLANNING EXERCISE

Confidential Advice to the Senior Attorney for Clean Air Now! (CLEAN!)

Even though GENCO, the electric company is a "public" utility, its planners have shown no aptitude for accommodating public concerns when developing projects. Specifically, the utility doesn't acknowledge social costs, i.e., environmental impacts or "externalities" in its planning process. These are significant, and you want them accounted for. Your staff scientists estimate them to be as follows:

Technology Type	Current Levelized Cost (¢/kWh)	+ Externality*	= Total (¢/kWh)
Life Extension of unit to be retired	4	+3	= 7
Gas Turbine Combined-Cycle	4	+1	= 5
Atmospheric Fluidized Bed	3	+3	= 6
Peak Load Management	4	+0	= 4
Conservation	4	-3	= 1

* Externality cost estimate based only on air pollution impacts, as discussed below. Significant site impacts, hazardous wastes, and worker safety risks were not quantified. Conservation gets negative cost (i.e., credit) for avoiding existing system-average emissions.

Your organization (CLEAN!) has made it an official policy position that it will intervene in regulatory hearings and in court against <u>any</u> proposals for new generation that are either less efficient or use a dirtier fuel than the current system averages. As you can see from the tables below, this means you should not sign any proposal recommending Life Extension or AFB coal technology. Those technologies will lead to a future that is even worse than the present.

There are two important technical concepts underlying these externality numbers. In essence, they are that pollution rates are affected by (1) combustion efficiency, and (2) fuel choice. The more efficient the combustion technology, the less air pollution will result per unit of output. The proposed supply-side options have reported efficiencies as follows:

Technology Type	Combustion Efficiency
Life Extension of unit to be retired	24%
Gas Turbine Combined-Cycle	42%
Atmospheric Fluidized Bed	37%
Existing System Average	34%

When fuel-specific pollution impacts are overlaid onto this efficiency information, then the following picture emerges for the pollutants sulfur (di)oxide(s) (SOx), nitrogen oxides (NOx), and carbon dioxide (CO2):

Technology Type	Pollutant	Lbs/1000 kWh	x	¢/Lb	=	¢/kWh Impact
Life Extension burning Oil #6	SOx	15		70	=	1.1
	NOx	6		300	=	1.8
	CO2	2238		0.1	=	0.2
						3.1 ¢/kWh
GT Combined Cycle burning Nat. Gas	SOx	0		70	=	0
	NOx	2		300	=	0.6
	CO2	935		0.1	=	0.1
						0.7 ¢/kWh
Atmos Fluidized Bed burning Bitumin. coal	SOx	11		70	=	0.8
	NOx	8		300	=	2.4
	CO2	1845		0.1	=	0.2
						3.4 ¢/kWh
Existing System Average	SOx	10		70	=	0.7
	NOx	6		300	=	1.8
	CO2	1800		0.1	=	0.2
						2.7 ¢/kWh

The utility systematically under-estimates the technical potential for conservation opportunities. Their estimate of the conservation resource available by 1995 (200 MW) is ludicrously low. Using the utility's own data, you have determined that all of the needed capacity over the planning period can be met with investments in conservation, and still be cheaper than the lowest-cost supply-side alternative, on a ¢/kWh basis, if pollution externality costs are included in the total cost. In other words, at an avoided cost of 5 ¢/kWh, the conservation resource approaches 500 MW.

You need to make sure that conservation is given the highest priority, because it is the most effective pollution reduction investment that can be made. You should push the group to recommend that the entire 400 MW increment of new capacity be done with conservation. Load management is your next highest priority in this planning effort, although it is a distant second to conservation because its pollution reduction impact is negligible. Conservation and load management are the least-cost alternatives from a societal point of view, and represent good investments from the narrow point of view of the utility as well. Getting the group to recognize the externality costs of pollution is a key piece of this argument.

The Public Utilities Commission may be a useful ally, but only within limits. It is working to restructure the utility's incentives to invest in capital-intensive options such as conservation, for example, by encouraging competitors like IPP to enter the picture. Similarly, conservation and load management may now be either passed through as an operating expense (like fuel) or earn a rate of return like a power plant. The Commission has a public charge to look after society's best interests, and that has, in the past, included an acknowledgement of the social costs of pollution. However, they are likely to continue to focus on a fairly narrow definition of "least-cost planning" that emphasizes the pocketbook impacts on electricity consumers more than the externality costs of pollution. Expend some effort to get them to broaden their perspective on least-cost planning.

In summary, your highest preference is for an all-conservation option. You also would be willing to accept a half-and-half load management plus conservation option, or, as a last resort, an efficient gas turbine combined-cycle plant. However, you cannot tolerate life-extension or AFB coal. It is unimportant to you whether GENCO or IPP is granted the right to build the option that is chosen. You are willing to accommodate other parties through contingencies or trade-offs, so long as your own priorities are met.

LEAST-COST PLANNING EXERCISE

Confidential Advice to the President of Independent Power Production, Inc. (IPP)

The Public Utility Regulatory Reform Act (PURPA) has been a law in name only during most of the time you have known the other parties in this negotiation. While the Public Utilities Commission claims that it seeks a truly competitive power market in your state, there is little evidence to indicate that it is serious, and the utilities themselves clearly do not want competition. You are going to need to fight for the right to enter the electricity generation business under fair terms in this state. Do not sign a planning proposal that includes any new utility-owned generating capacity, whether life-extension, combined-cycle, or AFB coal.

In particular, it is clear that the utility has stacked the deck against you on contract terms. It is your only major customer, and while you can threaten to bypass the utility and sell power directly to a major industrial consumer, that is not practical for more than a small fraction of the electricity your plant would produce. A few years ago, the utility tried to stick you with a short term "spot market" pricing contract, allowing them to purchase power from you whenever your price was less than their current costs of production. They knew that it would be impossible to get project financing under such a tenuous contracting arrangement. The PUC then forced them to offer you a long term contract guaranteeing adequate annual sales to justify your power plant investment. However, the utility demanded that your ¢/kWh price to them remain fixed in real terms over the length of the contract -- a risky proposition given the historical volatility of fuel prices.

With progressive deregulation, and the current local demand for natural gas outstripping its supply, there appears to a be a significant risk that future gas prices will approach those of Oil#2 on a per-Btu basis. Indeed, if natural gas prices jump even half as much in the next ten years as oil prices did in the previous decade, then the levelized cost per technological option could be expected to climb as follows:

Technology Type	Utility's Current Levelized Cost (¢/kWh) +	Additional Fuel Cost (¢/kWh) =	Total Cost (¢/kWh)
Life Extension of unit to be retired	4	+1	= 5
Gas Turbine Combined-Cycle	4	+1	= 5
Atmospheric Fluidized Bed	3	+0.5	= 3.5

Under the currently-offered fixed-rate contract, the only technology that you could build is the AFB coal plant. Coal prices exhibit much less volatility than gas and oil prices; thus the contract risk would be within acceptable limits.

A combined-cycle power plant (burning natural gas) would be a feasible technology only if you could get the contract terms modified to include an electricity price escalator that tracks fuel prices. If you can get the utility (and the PUC) to agree to this, then fuel-side risks can be shifted away from you to ultimate customers.

The silent partner in your venture has very deep pockets, so that you are not troubled by the magnitude of initial construction costs. You can easily finance the AFB coal plant ($600 million) or the GTCC plant ($200 million). GENCO, on the other hand, is so risk-averse that it is unwilling to commit adequate capital to meet the region's electricity needs.

The life extension technology option is not available to you, of course, because it applies only to existing, utility-owned facilities. However, the conservation and load management options may be worth considering, although you do not currently know much about them. You are certainly capable, in technical terms, of installing conservation measures, or in managing a load cooperative, but you would need a strong incentive structure and air-tight contractual arrangements to make financing obtainable. Assuming the utility will guarantee you a fixed payment per avoided kW or kWh of conservation or load management under a long term contract similar to the current offer described above (fixed real prices), then this option might be worth exploring. However, this path is a distant second choice. You know that the real money is to be made on supply-side investments.

You have good information on project initial costs, and you know that you can build either an AFB coal or a combined-cycle plant for less than the utility could. Thus your levelized costs (¢/kWh) will be less too, providing you with a decent return for your risky investment. Your cost of producing electricity is 0.1 ¢/kWh less than the utility's for combined-cycle technology, and 0.1 ¢/kWh less for AFB coal, as follows:

Technology Type	IPP's Levelized + Cost (¢/kWh)	Fuel Risk = Cost (¢/kWh)	Total Cost (¢/kWh)
Gas Turbine/Combined Cycle	3.9	+1	= 4.9
Atmospheric Fluidized Bed	2.9	+0.5	= 3.4
Peak Load Management	4*		= 4*
Conservation	4*		= 4*

* You have no better information than the utility regarding the costs of these technologies.

The attractiveness of your power plant investments depends in a dramatic way on future environmental regulations. If emissions standards change during the next few years, they could ruin your project's economics. You need to make sure that you understand the perceived "social" costs associated with emissions from each type of power plant. The magnitude of these costs is probably a good indicator of the direction future environmental regulations will take. Obviously, the viability of your project will also depend on the costs imposed by any future regulations.

In summary, your first choice is for you to build an AFB coal plant. Failing that, you would be willing to build a GTCC plant if you could pass fuel-side risks on to the utility. As a last resort, you are willing to invest in conservation and/or load management. However, you are unwilling to allow GENCO to build anything on the supply-side, whether life-extension, GTCC, or AFB coal. As long as your own needs get met, you will try to accommodate others.

LEAST-COST PLANNING EXERCISE

Confidential Advice to Professor Calme, the Mediator -- #1

The warring factions have turned to you because of your technical expertise in the fields of electric power systems engineering and planning. Collectively, they trust your technical judgement more than they trust each other. They have given you a mandate to talk to all of the parties to gather information and identify options. Feel free to meet with individuals to probe their interests. They hope that you will be able to distill all of the information you collect into a recommendation for a course of action that will satisfy everyone's needs. Of course, this recommendation must take account of the different concerns of the various parties.

It is your responsibility to make sure that the project that is chosen represents that one with the greatest net social benefit. Given that there are many costs and benefits associated with electricity production that are not accounted for in its final price, it is your responsibility to take a broad view of costs and benefits. Environmental impacts, risks imposed by uncertainty about the future, and other concerns must be considered along with actual dollar costs in this least-cost planning process. One of the fairest ways to do this is to find the dollar equivalents of pollution damage and fuel price uncertainty, for example, then include these values when evaluating the net benefit of each option.

You, better than anyone else at this table, know how uncertain the planning parameters are that must be dealt with in this decision. Since you started working as an engineer, you have seen load growth drop from "7% a year forever" to no growth at all, to the current average of 2% annually. Fuel prices have jumped all over the spectrum, environmental regulation has changed the economics of nearly every supply-side technology, and demand-side options have gained a place in the portfolio that they never before enjoyed. You must use good judgement in estimating the expected values of the many uncertain factors that go into your recommendation.

You will have to move quickly to garner enough information from each participant to present a plausible recommendation to the group. Each of the stakeholders probably will have different pieces of information relevant to the outcome of this planning exercise. You must elicit these, decide if they affect the relative attractiveness of the options, figure out how much confidence to place in what is said, help the group narrow in on a best option, and convince the parties that this is the best choice.

Be sure the group is comfortable having you play the role you have in mind for yourself. They will probably be more willing to let you help if you also agree to be the note taker and the time keeper.

LEAST-COST PLANNING EXERCISE

Confidential Advice to Professor Calme, the Mediator -- #2

The warring factions have turned to you because of your gray hair and the purported wisdom it connotes. They think that you are a reasonable person with a fairly neutral stance on the issues at hand. Although you are likely to have the best overall picture of the situation, each of the parties involved is likely to know more than you do about their particular high-priority issue or concern. Talk to the parties and get them to share information; feel free to meet separately with individuals or clusters of people to probe their interests. It is your responsibility to push them hard to find whatever common ground exists. Help them find a consensus option.

If this is like most technical discussions you have been involved in over the years, there will be detailed, intelligent analysis presented, most of which will yield conflicting or even contradictory recommendations. Part of your task is to hack through the jungle of assumptions that surrounds each position, and see whether there is a basis for agreement in spite of conflicting technical analysis.

Everyone at the table knows how uncertain key planning parameters are. Environmental impacts, risks imposed by uncertainty about the future, and other concerns must be considered along with actual dollar costs in this least-cost planning process. You probably won't be able to reach consensus unless you feel out the ranges of values that the different parties attach to different factors.

Instead of asking which is each person's favorite option, ask, "Is there an option that you cannot live with?" More generally, are there options that nobody likes, and can be discarded? Are there uncertainties that don't affect peoples' preferences, i.e., are irrelevant to their ordering of the options? Are there ways to measure uncosted impacts, such as air pollution and future fuel price uncertainties, that are acceptable to everyone? Work hard to get them to rank-order options. Try not to let them value these factors in more normative dollar terms.

You will have to work quickly to push the participants towards a common view of the problem. Get them to share information so that they can diagnose areas of disagreement. Be sure the group is comfortable having you play the role you have in mind for yourself. They will probably be more willing to let you help if you also agree to be the note taker and the time keeper.

The Open Planning Simulation – Negotiated Least-Cost Planning – EXPLANATORY CHART By Clinton J. Andrews

Option:	Life Extension		Gas Turbine Combined-Cycle		Atmospheric Fluidized Bed		Peak Load Management		Conservation	
Builder:	Utility	IPP	Utility	IPP	Utility	IPP	Utility	IPP	Utility	IPP
Player										
GENCO										
Preferences per text (1=best, 10=unacceptable)	1	Infeasible X	2	8	X(10)	7	9	6	X(10)	5
by levelized cost (¢/kWh) (lower is better)	5	X	4	4	3	3	4	4	4	4
by initial cost ($/kW) (lower is better, cap=1000)	100	X	600	600	X(1900)	1900	300	300	X(1300)	1300
CLEAN										
Preferences per text (1=best, 10=unacceptable)	X(10)	X	5	5	X(10)	X(10)	4	4	1	1
by level'd soc. cost(¢/kWh) (lower is better)	8	X	5	5	6	6	4	4	3	3
by efficiency, emissions (>34% and <10/6/1800)	X(24%) X(15/7/2238)	X	42% 0/2/935	42% 0/2/935	37% X(11/7/1845)	37% X(11/7/1845)	0 0	0 0	0 credit	0 credit
EPA										
Preferences per text (1=best, 10=unacceptable)	X(10)	X	1	2	9	9	5	6	3	4
by level'd cost (¢/kWh) ('91 regs)(lower is better)	5.2	X	4	4	3	3	4	4	4	4
by '94 CO2 emissions cap (>1200=unacceptable)	X(2238)	X	935	935	X(1845)	X(1845)	0	0	0	0
IPP										
Preferences per text (1=best, 10=unacceptable)	X(10)	X	X(10)	2	X(10)	1	6	5	6	5
by level'd cost (¢/kWh) w/ fuel risk (lower is better)	6	X	5	5	3.5	3.4	4	4	4	4
PUC										
Preferences per text (1=best, 10=unacceptable)	X(10)	X	X(10)	1	X(10)	1	9	9	2	2
by level'd cost (¢/kWh) w/ LM risk (lower is better)	5	X	4	4	3	3	5	5	4	4
Range of ¢/kWh (social) costs	5 to 8	X	4 to 5	4 to 5	3 to 6	3 to 6	4 to 5	4 to 5	3 to 4	3 to 4
Possible outcomes X = no consensus possible	X	X	X	Contingent on contract terms	X	X	W/ Conservat'n together	W/ Conservat'n &contract term	X	Contingent on contract terms

Note that the ¢/kWh (social) costs cover a wide range for each option, so that decisions based on that criterion alone will be fairly difficult to make.

Note that the underlying criteria, such as efficiency and emissions, show greater consistency across players.

APPENDIX A3:

QUESTIONNAIRE FOLLOWING-UP THE NEGOTIATED LEAST-COST PLANNING SIMULATION

Least-Cost Planning Exercise
Follow-Up

Please fill this out and return it before you leave (answers kept confidential).

Your role in game (check one):

Utility (GENCO) ______
Regulator (PUC) ______
Environmental Group (CLEAN!) ______
Consumer Group (NOPE) ______
Independent Power Producer (IPP) ______
Professor Calme (Mediator) ______

You were at Table ________

Your role in real life (check one):

Electric Utility Management ______
  Legal Counsel ______
  Planning ______
  Rates ______
  Public Affairs ______
Public Utility Regulator ______
Attorney General/ Justice ______
Consumer Advocate ______
Environment Department ______
Other Government (specify) ______
Environmental Group ______
Small Consumers Group ______
Industrial/Commercial
  Electricity Consumer ______
Independent Power Producer ______
Other Energy Supplier
  (specify) ______ ______
Mediator / Dispute Resolution
  Professional ______
Electric Power Industry
  Expert/Consultant ______
Other (specify) ________ ______

Game Outcome (check one): Consensus _____ Impasse _____

If a consensus was reached, what was the chosen plan? ________________________________

Which negotiating strategies did you try in the game, and which ones worked?

	Tried	Worked
Focus on interests, not positions	______	______
Invent options for mutual gain	______	______
Insist on objective criteria	______	______
Separate the people from the problem	______	______
Know your Best Alternative to Negotiated Agreement	______	______
Others (specify) ____________________________	______	______

Identify the hardest obstacles for you to overcome during the simulation. What would you expect them to be in your real job, if you participated in an actual negotiated least-cost planning process? (prioritize: 1= important, 5= unimportant)

	In the game?	Expected in real life?
Conflicting interests of parties	______	______
Differing perceptions of main issues	______	______
Conflicting technical information	______	______
Disparate values for non-dollar "intangibles" (pollution impacts, catastrophic risks, etc.)	______	______
Polarization around different options	______	______
Uncertainty about the future	______	______
Unequal background/technical understanding	______	______
Others (specify) ________________________	______	______

Was the mediator an important influence on the outcome of the game (check one)?

Yes _____ No _____ (If no, then who was? _________)

Prioritize the mediator's (or other active participants') most important positive procedural contributions (1=important, 5=unimportant).

	In the game?	Expected in real life?
Identifying issues of primary importance to the planning effort	______	______
Timekeeping/Notetaking	______	______
Serving as a safe, neutral channel for confidential information	______	______
Getting parties to share information with each other	______	______
Pushing the parties to reach an agreement	______	______
Recommending a course of action that results in a consensus	______	______
Getting an agreement that covers contingencies	______	______
Others (specify) ________________________	______	______

Prioritize the mediator's (or other active participants') most important analytical contributions (1=important, 5=unimportant).

	In the game?	Expected in real life?
Discarding options that someone could not accept	______	______
Identifying options that everyone could accept	______	______
Discarding irrelevant issues/uncertainties	______	______
Uncovering common ground underneath conflicting statements	______	______
Eliciting ranges of values different parties perceive for factors	______	______
Finding a way to prioritize options that satisfies everyone	______	______
Analyzing shared information and finding best option	______	______
Inventing packages of options to discuss	______	______
Finding a common numeraire for valuing diverse impacts	______	______
Others (specify) ________________________	______	______

In real life, who would you trust to serve in the neutral, or mediator's role (1= 1st choice, etc.)?

University/Academic ______
Government Official (specify) ______
Other (specify) ____________ ______
Technical Expert/Consultant ______
Dispute Resolution Professional ______
None ______

Who would you trust to provide technical information and analysis for the group (1= 1st choice, etc.)?

University/Academic ______
Government Agency (specify) ______
Utility Planning Department ______
National Laboratory ______
Other (specify) ____________ ______
Technical Expert/Consultant ______
Dispute Resolution Professional ______
"Blue Ribbon" Committee ______
None ______

Please characterize the "ideal" analytic approach for use in an open, or negotiated planning process by choosing how to end each sentence below (circle one word in each sentence).

Time demands of analytic effort on decision makers (not analysts) should be:
"Minimal."
"Extensive."
Other (specify).

Analytic assumptions should be based on:
"Expert judgement."
"Group assumption-making."
Other (specify).

Measure impacts with:
"An aggregate measure, say $."
"Multiple measures, say $, SOx, LOLP."
Other (specify).

The analysis should:
"Identify the optimal choice."
"Explicate tradeoffs among options."
Other (specify).

Regarding the future, the analysis should:
"Carefully define most probable base case."
"Analyze many possible scenarios."
Other (specify).

Options should be:
"Rank-ordered (1st, 2nd, 3rd,...)."
"Valued in $ terms (greatest net benefit)."
Other (specify).

Successful mediation must be:
"Technically substantive."
"Process-only."
Other (specify).

In real life, have you participated in a negotiated, or open planning process of the sort modeled in the Least-Cost Planning Simulation?

Yes ______ No ______

If yes, how may I find out more about it? Contact name/phone/address ________________

____

What are your greatest concerns regarding the feasibility of an open, or negotiated least-cost planning process?

What analysis techniques would be useful in such a context?

Was the simulation useful in characterizing what to expect in a real open planning process?

Very useful ____ Somewhat useful ______ Not useful ______

Please share any comments you have about the design of the simulation.

Your name (OPTIONAL): ________________________________

Thank you for answering these questions. The results will provide guidance for dissertation research on ways to improve the analytics of electric utility open planning processes. Please contact me if you have any further insights that you are willing to share, or any questions.
– Clinton J. Andrews, Ph.D. candidate, Department of Urban Studies and Planning/Energy Laboratory, Room E40-481, M.I.T., Cambridge MA 02139. Telephone: (617) 253-7985.

APPENDIX B1:
PARTICIPANTS' LISTFOR THE NEW ENGLAND PROJECT

THE NEW ENGLAND PROJECT ADVISORY GROUP

Advisory Group Members

Chairman
Connecticut Dept.of Public Utility
Control

Chairman
Maine Public Utilities Commission

Commissioner
Massachusetts Dept.of Public Utilities

Commissioner
New Hampshire Public Utility
Commission

Asst. to the VP of Power Supply
Supervisor of System Planning
Central Maine Power Company

President and Chief Oper. Officer
Commonwealth Electric Company

Vice President
Staff Assistant
Eastern Utilities Associates

Assistant Vice President
Green Mountain Power Corp.

VP, Demand and Least Cost Planning
New England Power Service Co.

Dir. of Corp. Planning and Economics
Director of System Planning
Northeast Utilities Service Co.

Director of External Coordination
New England Power Pool

Director
New England Power Planning

Senior Attorney
Technical Advisor
Conservation Law Foundation
of New England, Inc.

Division Director - Waste Mgmt
Environmental Protection Agency,
New England Region

Director
Northeast States for Coordinated
Air Use Management

Economist
The Federal Reserve Bank of Boston

Vice-President
Massachusetts Business Roundtable

President
Special Assistant to the President
MITRE Corporation

Senior Vice President
Raytheon Company

Invited to Attend/Join the Advisory Group

Chairman
R.I. Public Utilities Commission

Chairman
Vermont Public Service Board

Vice President of Energy Planning
Boston Edison Co.

Asst. VP of Energy Planning
Central Vermont Public Service

Vice President
The United Illuminating Co.

Director of Building Operations
John Hancock Mutual Life Insurance Co.

Energy Policy Analyst
MASSPIRG

President
New England Cogneration Assoc.

President, New England Chapter
Sierra CluB

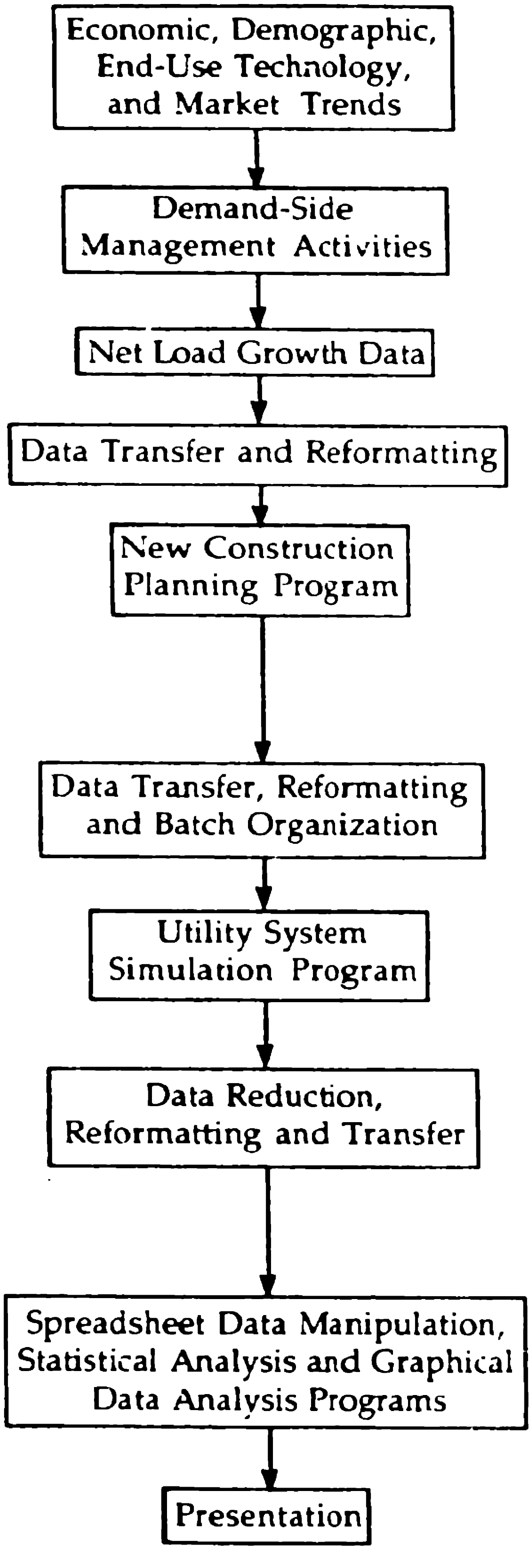
Staff Member
Office of the Lieutenant Governor, Mass.

Staff Member
Mass. Attorney General's Office

APPENDIX B2:

THE TECHNICAL ANALYTICS OF OPEN PLANNING IN NEW ENGLAND

New England Project
Scenario Analysis Process



A variety of trajectories for national & regional economies, population, end-use technology characteristics, user behavior, market penetration, and other drivers of "raw" load growth are entered, for hundreds of end-uses, into the NEPOOL Load Forecasting Model (NEPLFM).

"Raw" loads are adjusted on an hourly basis by demand-side options such as utility programs, standards and subsidies in the NEPLFM. Costs are tracked in a series of spreadsheets.

Adjustments for factors such as customer generation give monthly net loads.

Load data are transferred from NEPOOL VAX to MIT Mac computers, reduced & reformatted.

New power plant capacity expansion planning under uncertainty is done by setting technology (%) and reserve margin targets, committing plants based on historical trends, and cancelling during lead time if subsequent load growth indicates. Output from program is a 20 year construction trajectory.

Load, construction, fuel, financial, and other data are reformatted & transferred from Mac to MicroVax, and organized to allow large batch scenario simulations.

The EPRI EGEAS probabilistic system simulation model is run for each scenario. It provides production costing, emissions, fuel use, financial, and operational data for the 300+ power plants on the New England grid over 20 years.

A program extracts key annual data from the voluminous EGEAS output reports for each scenario. These are transferred from MicroVax to Mac, reformatted, and condensed to cumulative (NPV) data for each scenario, forming the scenario data set, in macro-driven spreadsheet form.

Data analysis and "story" development are performed in Excel spreadsheets, the Systat statistical programs, the Cricketgraph, MacSpin, and Superpaint graphics programs, and in Word.

The results of this analysis are shared with the advisory group.

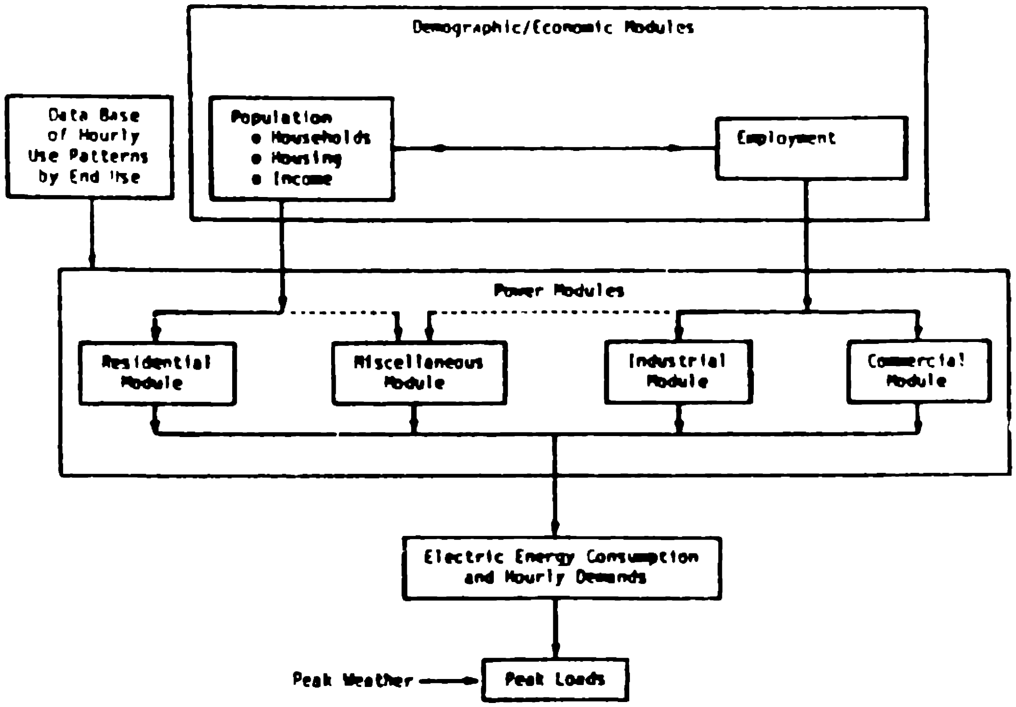
NEPOOL Load Forecasting Model

Load forecasts forming the basis for the scenarios in the New England project are generated using the NEPOOL Load Forecasting Model (NEPLFM). This integrated system was developed at Battelle Labs and is maintained by a group of full-time staff at NEPLAN. It resides on the NEPOOL computer in West Springfield, MA and is accessed by telephone from MIT. The information below is excerpted from the NEPLFM documentation, which is available from NEPLAN (1981 - 1990).

The system has four major elements: (1) a user interface that allows either batch or interactive operations, (2) a group of load forecasting models covering different sectors and providing alternative methods for forecasting within each sector, (3) a data base management system, and (4) a group of data bases.

It is an electrical end-use load forecasting model that tracks 30 residential end-uses, 8 end-uses for each of 10 commercial building types, 18 industrial SIC codes, and 4 miscellaneous end-uses. Each end-use is modeled for each of the six New England states, and can be aggregated to the regional level. It does this on an hourly basis, providing detailed loads for 8760 hours of each forecast year. This information can be aggregated into trajectories of regional peak and energy over time.

Logical Structure of the NEPOOL Model NEPLFM (NEPLAN, 1982)



Modeling Demand-Side Management Programs in NEPLFM

Demand-side management activities are modeled in two ways in the NEPLFM. First, the model input assumptions can be changed to reflect different conditions. For example, residential appliance efficiency standards will alter the trends in appliance energy efficiency over time; likewise, commercial lighting subsidies will reduce the unit cost of high-efficiency lamps, leading to a larger market share for that technology.

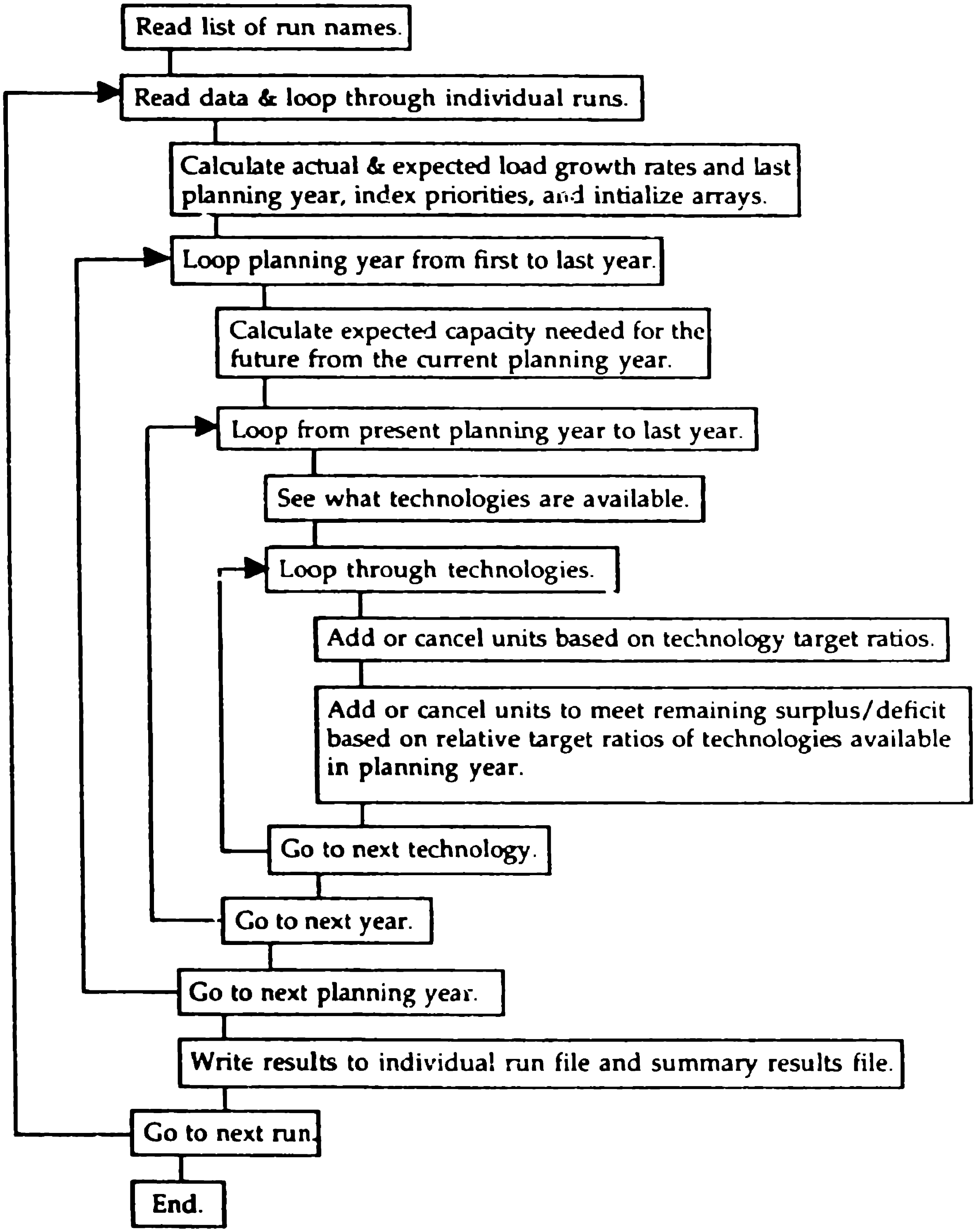
The second approach is to reduce the total connected load for an end-use by some amount relative to its level without DSM programs. For example, current utility programs in Massachusetts are expected to reduce residential room air conditioning loads some 10% relative to the no-DSM case. The table below illustrates this approach by listing the expected impact of current utility programs on appliance connected load for Massachusetts (NEPLAN 1989).

DMT. ENERGY MANAGEMENT PROGRAM IMPACT ON APPLIANCE CONNECTED LOAD, MASSACHUSETTS, 1990 TO 2005

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
RANGE	0.999	0.998	0.997	0.996	0.995	0.995	0.994	0.994	0.993	0.993	0.991	0.988	0.984	0.981	0.977	[illegible]
REFRIGERATOR.FF	0.996	0.994	0.991	0.988	0.986	0.984	0.983	0.981	0.981	0.981	0.979	0.976	0.971	0.967	0.962	0.959
REFRIGERATOR.STD	0.996	0.994	0.991	0.988	0.986	0.984	0.983	0.981	0.981	0.981	0.979	0.976	0.971	0.967	0.962	0.959
FREEZER.FF	0.999	0.999	0.998	0.998	0.997	0.997	0.996	0.996	0.996	0.996	0.994	0.990	0.985	0.981	0.975	0.972
FREEZER.STD	0.999	0.999	0.998	0.998	0.997	0.997	0.996	0.996	0.996	0.996	0.994	0.990	0.985	0.981	0.975	0.972
DISHWASHER	0.999	0.999	0.998	0.998	0.997	0.997	0.996	0.996	0.996	0.996	0.994	0.990	0.985	0.981	0.975	0.972
CLOTHES WASHER	0.998	0.997	0.996	0.995	0.995	0.994	0.993	0.992	0.992	0.991	0.989	0.986	0.981	0.976	0.971	0.967
CLOTHES DRYER	0.999	0.998	0.998	0.997	0.997	0.996	0.996	0.995	0.995	0.993	0.993	0.989	0.984	0.980	0.974	0.971
WATER HEATER.CTR	0.954	0.943	0.936	0.941	0.944	0.942	0.941	0.939	0.939	0.939	0.937	0.934	0.930	0.927	0.922	[illegible]
WATER HEATER.UNCTR	0.954	0.943	0.936	0.941	0.944	0.942	0.941	0.939	0.939	0.939	0.937	0.934	0.930	0.927	0.922	[illegible]
MICROWAVE OVEN	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
COLOR TELEVISION	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
B/W TELEVISION	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
LIGHTING	0.985	0.978	0.970	0.963	0.957	0.955	0.954	0.952	0.952	0.952	0.950	0.946	0.942	0.938	0.933	[illegible]
MISCELLANEOUS	1.004	1.002	0.998	0.991	0.982	0.974	0.966	0.959	0.955	0.951	0.927	0.892	0.843	0.794	0.728	[illegible]
ROOM A/C	0.991	0.983	0.975	0.965	0.957	0.952	0.948	0.946	0.944	0.943	0.939	0.934	0.927	0.920	[illegible]	[illegible]
CENTRAL A/C	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
ELECTRIC HEATING	0.994	0.990	0.984	0.977	0.971	0.967	0.965	0.961	0.962	0.961	0.957	0.952	0.946	0.940	[illegible]	[illegible]
FOSSIL HEATING AUX.	0.999	0.999	0.998	0.998	0.997	0.997	0.996	0.996	0.996	0.996	0.994	0.990	0.985	0.981	0.979	0.972
SECOND HOMES	1.010	1.013	1.015	1.016	1.016	1.017	1.017	1.018	1.018	1.018	1.018	1.017	1.017	1.016	1.015	1.014
STORAGE E/H	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
ESH - WOOD STOVES	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
HEAT PUMP - FHA	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CONTROLLED E/H	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
STORAGE WATER HEATER	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CONTROLLED RAC	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CONTROLLED CAC	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SOLAR WATER HEATER	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
HEAT PUMP - E/H	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
HEAT PUMP - A/C	1.000	1.0 0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

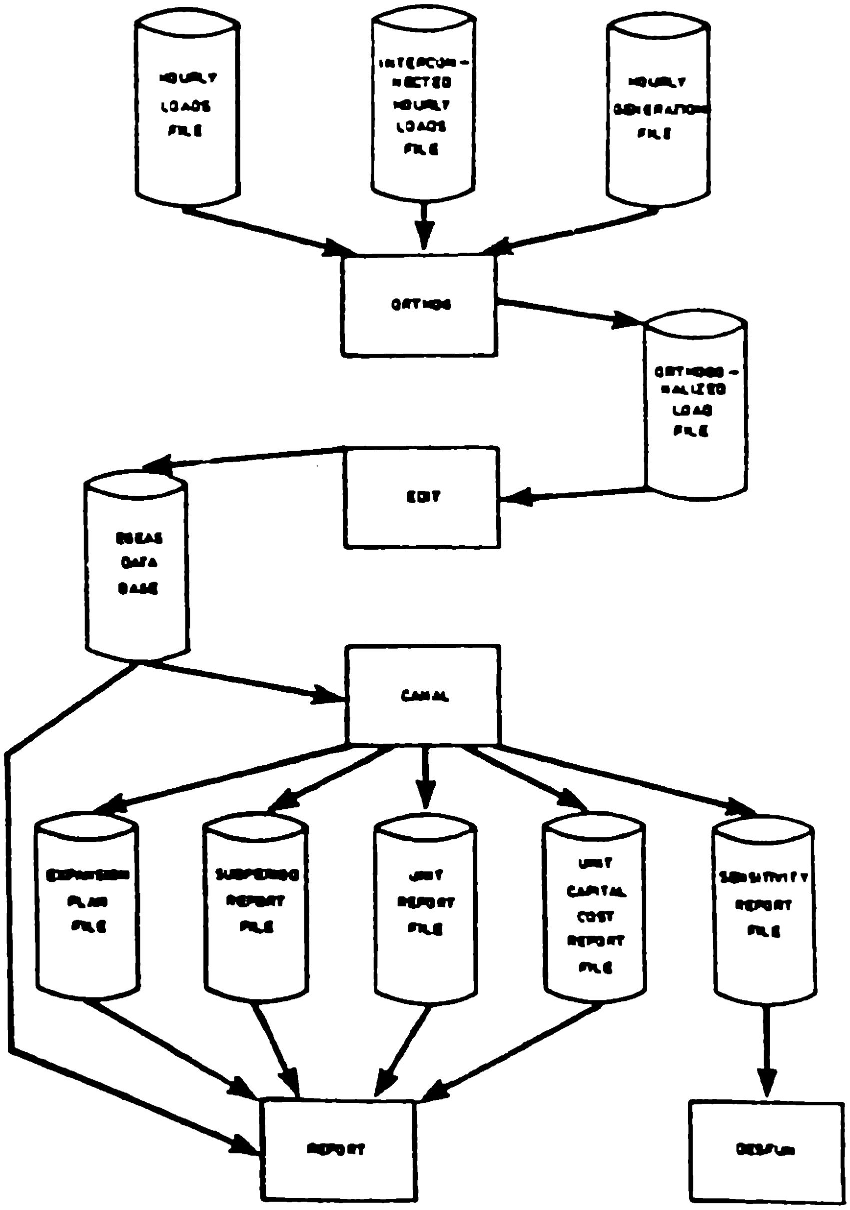
New Construction Planning Program: Pre-Specified Pathway (PSP)

PSP Algorithm Flowchart



Utility System Simulation Program

The main utility operations and capacity expansion planning program used on the New England project is EGEAS (Electric Generation Expansion and Analysis System) (EPRI, 1989). The four main modules of this package include ORTHOG, which translates hourly load data into probabilistic load duration curves; EDIT, which performs error checking and creates the main data base; CANAL, which performs detailed production costing, dispatch, and financial calculations; and REPORT, which produces formatted output. It is operated in the annual simulation mode, using capacity expansion plans developed by the PSP program. A system diagram follows.



Integrating the Models

Several Fortran programs and macro-driven Excel spreadsheets were written that provide the connective tissue between the major models. In order to expedite the running of thousands of scenarios, it was necessary to partially automate the data transfer between models, and the user's sequential operations to run each model. The main pieces of integrative programming are listed below.

Scenario Generator: takes detailed output from the NEPLFM and reduces the data to annual peak and energy trajectories for each scenario.

Load-Related Inputs: creates trajectories of loads, fixed costs, and other load-related information for input into EGEAS in Excel spreadsheet form.

EGEAS Setup Templates: are in Excel spreadsheet form, allowing easy editing of basic input data.

Input Reformatters: are Fortran programs that read in the EGEAS Setup Templates and write out EGEAS-formatted input files.

EGEAS ComFiles: Vax VMS comfiles that organize the various EGEAS input files, select those needed for the current run, operate EGEAS in batch mode, and delete unneeded output files after the run.

Extract: is a Vax Fortran program that reads in the EGEAS output files, reduces the data, and writes out a multi-attribute vector for each scenario in tab-delimited form for export onto the Macintosh and into an Excel spreadsheet.

AttPro: is a set of Excel macros that further reduces the scenario data, adds cost information developed in spreadsheets running parallel with EGEAS, and produces a complete scenario data set.

Systat Comfiles: direct Systat to produce a standard series of graphics needed for inductive data analysis.

Excel Macros: manipulate data to make analysis easier, to produce data in formats suitable for easy graphical presentation in Cricketgraph, Macspin, and Systat.

APPENDIX B3:
QUESTIONNAIRES EVALUATING THE NEW ENGLAND PROJECT

June 20th 1989 Questionnaire to New England Project Advisory Group

Primary Issues Raised

Two issues were carried over from the April 24 meeting and reaffirmed as major research foci:

- Environmental impacts of different supply/demand strategies
- Reliability of electricity supplies given supply/demand strategy and uncertainties

The following issues were added to the overall research effort:

- Regional economic competitiveness
- Structural change in the electric power industry, and
- Transmission, and spatial investment/siting impacts in general

Discussion of the newly introduced issues focused on the feasibility of their incorporation into the proposed study. General agreement on their incorporation was as follows:

- Regional economic competitiveness will be incorporated into the study by restructuring the global/overall attributes and uncertainties.

- Structural changes in the electric power industry are incorporated into the study implicitly by the choice of supply/demand strategies being evaluated. For example, a strategy in which all new supplies are contracted from demand-side vendors, IPPs and cogenerators is essentially a electric utility as distributor strategy, and reflects a structural change in the industry.

- Transmission capabilities, while an increasingly important issue in the region's future ability to meet demand, are difficult to model directly using the proposed planning tools. However, every effort will be made to incorporate the costs, and constraints associated with transmission into the analysis and scenario formulation.

The following sections review the attributes discussed, broken down by issue and sub-issue. Time prohibited us from soliciting your personal preferences and prioritization of the issues presented on the 14th. If you could identify which issues you feel are *most* important, and fax a copy of these sheets back to us it would be greatly appreciated. The Energy Lab fax number is 617/253-8013.

Environmental Sub-Issues and Attributes

• Acid Deposition[1]				
[__] SO$_x$	(tons/yr.)	(lbs/kWh)	(Cum. tons)	
• Air Quality				
[__] NO$_x$	"	"	"	
[__] Suspended Particulates	"	"	"	
• Solid Wastes				
[__] Solid Waste/Sludge		"	"	"
[__] Spent Nuclear Fuel		"	"	"
• Climate Change				
[__] CO$_2$	"	"	"	
• Land Use Impacts				
[__] Land Use[2]	(acres/MW)	(total new acres)		(Cum. acres)
• Water Use				
[__] Water Use	(Volume-Q)	(Q/MW,kWh)	(ΔTemp.)	

Other environmental sub-issues...

- Changes in Capital Stock
- Regulatory Impacts
  - Changes in Source Emission Standards
  - Utility vs. Non-Utility Standards
  - Incorporating Externality Costs
- Noise, Traffic, and Visual Impacts

The attributes associated with these sub-issues are covered by those above, those under the heading Overall Attributes or as descriptions of the scenarios themselves.

---

[1] whenever possible the environmental emissions associated with purchased power will be incorporated into the analysis

[2] includes estimations of plant footprint, fuel storage, holding pools, substation and transmission connection areas wherever possible

Reliability Sub-Issues and Attributes

- Capacity Shortfalls

[__] NEPOOL OP-4 Danger Hours

	(ann. per action)	(cum. per action)	(hours in any action)
— CONVEX	..	..	..
— REMVEC	..	..	..
— Maine	..	..	..
— New Hampshire	..	..	..

[__] Deficit Duration Curves (annual)
[__] System Unmet Energy (GWh/yr)(GWh Cum.)

- Changes in Capital Stock

[__] Average System FOR (% annual)(% final)

- Reliability at Meter

[__] Unmet Energy at Meter .. ..

Other reliability sub-issues...

- Non-Utility Impacts on System Reliability
- Reliability/Availability of Power Purchases
- Customer Responsiveness — to interruptibles, time of use rates, DSM initiatives, etc.
- Customer Incurred Costs associated with outages, voltage reductions, etc.

Examples of Overall Attributes

- Cost

		(20 yr. NPV)	(total annual)	(levelized ¢/kWh)	(annual ¢/kWh)
[__]	Revenue Requirements				
[__]	Combined Utility & Customer Costs		"	"	"
[__]	Investment in Supply (utility)	"	"	"	"
[__]	Investment in Supply (total)	"	"	"	"
[__]	Investment in Demand (utility)		"	"	"
[__]	Investment in Demand (total)	"	"	"	"
[__]	Investment in Demand (non-partic.)		"	"	"

[__] Long-Run Marginal Cost (avoided cost curves) (annual ¢/kWh)
[__] Short-Run Marginal Cost (annual cost-duration curves) (annual ¢/kWh by demand)

- Fuel Mix

[__] GWH generation by fuel type (annual)(cumulative)
[__] Consumption by fuel type by source " "
[__] Forced fuel switching (annual %)(total %)

- Installed Capacity

[__] Plant Age (system average by yr., by MW, by GWh)
[__] Heat Rate "

- Employment

[__] construction related man-years (annual) (cumulative)(% DSM man-hrs)
[__] direct/indirect multipliers " "

Environmentally-Related Uncertainties

- [__] Annual Energy Use
- [__] Fuel Use and Availability
- [__] Emission Regulations
  - [__] Changes in Source Emission Standards
  - [__] Utility vs. Non-Utility Standards
  - [__] Incorporating Externality Costs
- [__] Availability of New Technologies
  (Clean Coal, Advanced Combustion, Nuclear, Renewables, DSM Advances)

Reliability-Related Uncertainties

- [__] Peak Electricity Demand (MW)
- [__] Third-Party Dropout Rate (% award pool—MW, No. of units)
- [__] Construction Lead Time (yrs. by technology)
- [__] Changes in Outage/Availability Rates
  - [__] Aging Capacity
  - [__] New Technologies
  - [__] Power Purchases, Emergency Assistance, etc.

Overall Uncertainties

- [__] Peak Electricity Demand
- [__] Annual Energy Demand
- [__] Load Shape
- [__] Fuel Prices and Availability
- [__] Investment Costs (technology, cost of capital)
- [__] DSM Participation Rates or Ability to Implement DSM Programs
- [__] Regulatory Constraints
- [__] Technology Availability (availability of new tech's, lead-times, etc.)
- [__] Capacity Performance (Utility vs. Non-Utility supplies)

Examples of Demand-Side Options

A Technological Component plus an Operational Component equals an Option

Major Category	Technological Component
Residential (29 End-Uses)	
Conservation	Appliances Building Envelope Heating Cooling Lighting, etc.
Load Management	Water Heater-DLC Air Conditioning-DLC Storage Heater, etc.
Commercial (8 End-Uses by 10 Bldg. Types)	
Conservation	Building Envelope Lighting HVAC Rehab. Refrigeration Rehab., etc.
Load Management	Thermal Storage, etc.
Industrial (18 Industries)	
Conservation	Motor Drive Replacement Process Heating Rehab. Lighting HVAC Rehab., etc.
Load Management	Thermal Storage, etc.
Other (3 End-Uses)	
Conservation	Street Lighting Farm Equipment Transmission Lines, etc.
Load Management	Electric Vehicles, etc.

Operational Component

Rebates

Utility Audits

Utility Installation

Third Party Installation

Shared Savings

Education/Marketing

Subsidized Materials
(Self Installed)

Regulations/Standards

Time of Use Rates

Interruptible Rates

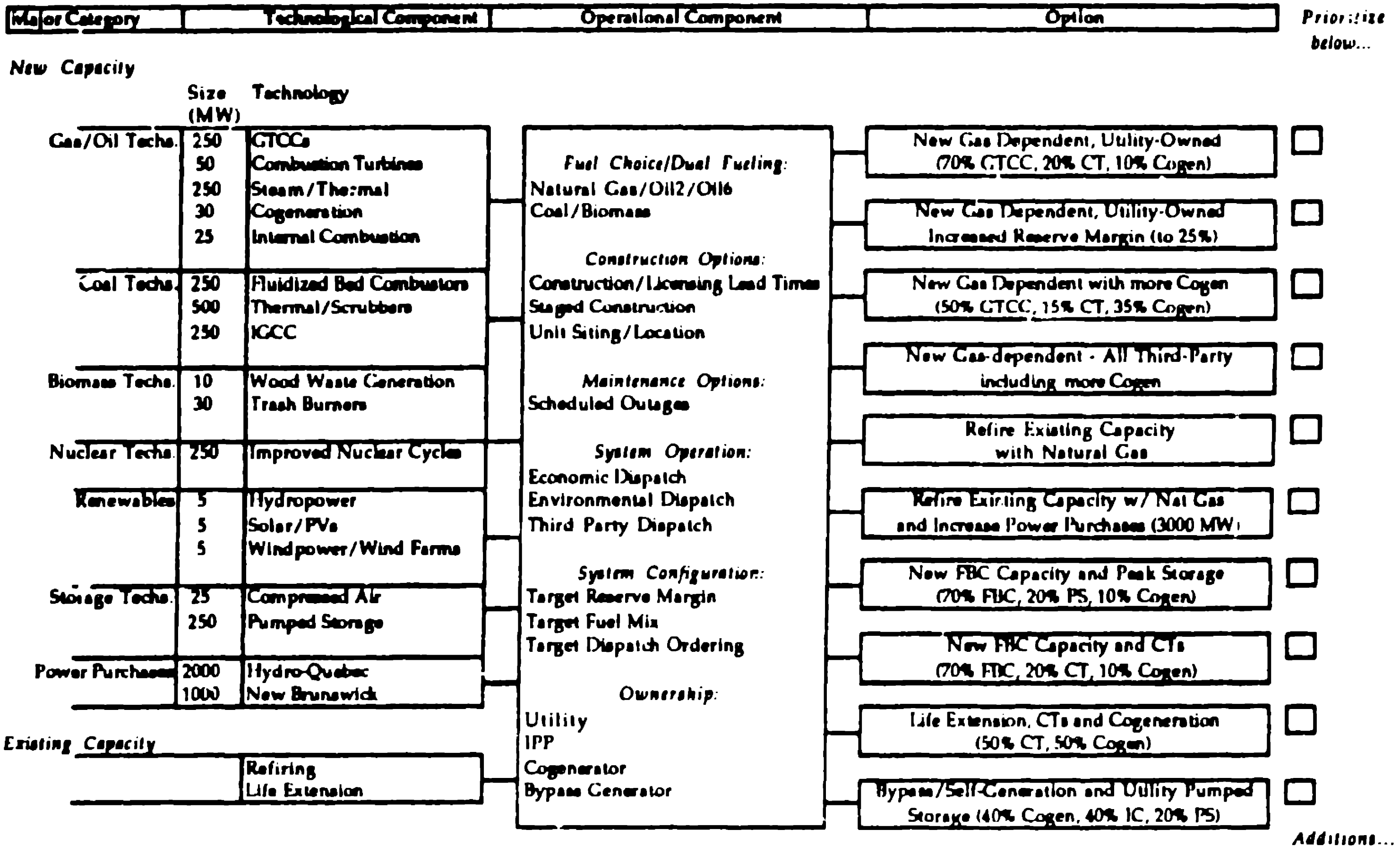
etc.

Option	*Prioritize below...*
Regionalized "Massachusetts Collaborative Process " with Budget Cap	☐
Regionalized "Massachusetts Collaborative Process " with no Budget Cap	☐
"Power to Spare" with Budget Cap	☐
"Power to Spare" with no Budget Cap	☐
Conservation Only	☐
NEPOOL CELT Report Extended	☐
No Additional DSM Activity	☐

Additions...

Examples of Supply-Side Options

A Technological Component plus an Operational Component equals an Option



Major Category	Size (MW)	Technology
New Capacity		
Gas/Oil Techs.	250	GTCCs
	50	Combustion Turbines
	250	Steam/Thermal
	30	Cogeneration
	25	Internal Combustion
Coal Techs.	250	Fluidized Bed Combustors
	500	Thermal/Scrubbers
	250	IGCC
Biomass Techs.	10	Wood Waste Generation
	30	Trash Burners
Nuclear Techs.	250	Improved Nuclear Cycles
Renewables	5	Hydropower
	5	Solar/PVs
	5	Windpower/Wind Farms
Storage Techs.	25	Compressed Air
	250	Pumped Storage
Power Purchases	2000	Hydro-Quebec
	1000	New Brunswick
Existing Capacity		Refiring Life Extension

Operational Component

Fuel Choice/Dual Fueling:
Natural Gas/Oil2/Oil6
Coal/Biomass

Construction Options:
Construction/Licensing Lead Times
Staged Construction
Unit Siting/Location

Maintenance Options:
Scheduled Outages

System Operation:
Economic Dispatch
Environmental Dispatch
Third Party Dispatch

System Configuration:
Target Reserve Margin
Target Fuel Mix
Target Dispatch Ordering

Ownership:
Utility
IPP
Cogenerator
Bypass Generator

Option — *Prioritize below...*

- New Gas Dependent, Utility-Owned (70% GTCC, 20% CT, 10% Cogen) ☐
- New Gas Dependent, Utility-Owned Increased Reserve Margin (to 25%) ☐
- New Gas Dependent with more Cogen (50% GTCC, 15% CT, 35% Cogen) ☐
- New Gas-dependent - All Third-Party including more Cogen ☐
- Refire Existing Capacity with Natural Gas ☐
- Refire Existing Capacity w/ Nat Gas and Increase Power Purchases (3000 MW) ☐
- New FBC Capacity and Peak Storage (70% FBC, 20% PS, 10% Cogen) ☐
- New FBC Capacity and CTs (70% FBC, 20% CT, 10% Cogen) ☐
- Life Extension, CTs and Cogeneration (50% CT, 50% Cogen) ☐
- Bypass/Self-Generation and Utility Pumped Storage (40% Cogen, 40% IC, 20% PS) ☐

Additions...

Examples of Combined Demand and Supply Strategies

A set of Demand Options plus a set of Supply Options equals a Strategy

Demand Options			Supply Options			Combined Strategies	*Prioritize Below...*
Regionalized "Mass. Collab. Process" -- No Budget Cap	100%	+	none	0%	=	"Demand-Side Efficiency"	☐
"Power to Spare" -- No Budget Cap	100%	+	Bypass/Self-generation & Utility Pumped Storage	0%	=	"Customer Investment"	☐
Regionalized "Mass. Collab. Process" -- Budget Cap	75%	+	Life Extension, CTs and Cogeneration	25%	=	"Avoiding Major Plants"	☐
"Power to Spare" -- Budget Cap	75%	+	Refire Existing Capacity with Natural Gas	25%	=	"Clean Combustion with Siting Constraints"	☐
Regionalized "Mass. Collab. Process" -- Budget Cap	66%	+	Refire Existing Capacity & Increase Power Purchases	34%	=	"No New Generation Sites"	☐
"Power to Spare" -- Budget Cap	66%	+	New Gas-dependent -- All Third Party	34%	=	"Restructured Industry"	☐
Regionalized "Mass. Collab. Process" -- Budget Cap	50%	+	New Gas-dependent with more Cogen	50%	=	"Demand- & Supply-Side Efficiency"	☐
"Power to Spare" -- Budget Cap	50%	+	New Gas-dependent -- Utility-Owned	50%	=	"Utility-Owned Balanced Portfolio"	☐
Conservation Only	50%	+	New Gas-dependent & Increase Reserve Margin	50%	=	"Balance Emphasizing Reliability"	☐
Conservation Only	25%	+	Refiring, Imports and Cogeneration	75%	=	"Cauticus Conservation"	☐
NEPOOL CELT Report Extended	25%	+	New Gas Dependent -- Utility-Owned	75%	=	"Status Quo"	☐
No Additional DSM Activity	0%	+	New FBC Capacity and Peak Storage	100%	=	"Supply Efficiency"	☐
No Additional DSM Activity	0%	+	New FBC Capacity and CTs	100%	=	"Traditional Supply-Side"	☐

Additions...

January 1990 Questionnaire to New England Project Advisory Group

One of the goals of the New England Project is to test the efficacy of alternative planning processes and analytic tools with a group of high-caliber decision makers. As the first step in doing this, I would like to know your feelings about the project while it is still in its early stages. I am interested in hearing your views on process, analysis, and role-related questions.

Please fill this out and return it before you leave (answers kept confidential).

What should/should not be major goals of this project?
(Score as follows: 5=important goal,...4...3...2..., 1=unimportant goal, 0=should not be a goal)

Prioritizing the most important regional electricity planning issues ______

Joint fact-finding about relevant
- historical data (ex.-reliability trends) ______
- locally unknown information (ex.-DSM unit costs) ______
- generally unresearched information (ex.-DSM reliability impact) ______
- uncertain future information (ex.-future load growth) ______

Evaluating regional planning alternatives:
- technological options (ex.-combustion turbine) ______
- strategies or packages of options (ex.-"Collaborative DSM") ______

Monetizing intangible impacts, such as pollution costs ______

Developing a shared understanding of the implications of different choices ______

Inventing better strategies than are currently on the table ______

Seeking an informed consensus on a course of action ______

Please characterize the "ideal" analytic approach for use in the New England project by choosing how to end each sentence below (circle one word in each sentence).

Time demands of analytic effort on decision makers (not analysts) should be:
"Minimal."
"Extensive."
Other (specify).

Analytic assumptions should be based on:
"Expert judgement."
"Group assumption-making."
Other (specify).

Measure impacts with:

"An aggregate measure, say $."
"Multiple measures, say $, SOx, LOLP."
Other (specify).

The analysis should:

"identify the optimal choice."
"Explicate tradeoffs among options."
Other (specify).

Regarding the future, the analysis should:

"Carefully define most probable base case."
"Analyze many possible scenarios."
Other (specify).

To aid in decision-making, options should be:

"Rank-ordered (1st, 2nd, 3rd,...)."
"Valued in $ terms (greatest net benefit)."
Other (specify).

Management of the Advisory Group meetings should be:

"Technically substantive."
"Process-only."
Other (specify).

Prioritize the MIT analysis team's most important procedural responsibilities.
(5=important, ..., 1=unimportant)

Identifying issues of primary importance to the planning effort _______
Serving as a safe, neutral channel for confidential information _______
Pushing the parties to reach an agreement _______
Recommending a course of action that results in a consensus _______
Discarding options that someone could not accept _______ _______
Identifying options that everyone could accept _______ _______
Discarding irrelevant issues/uncertainties _______ _______
Uncovering common ground underneath conflicting statements _______ _______
Eliciting ranges of values different parties perceive for factors _______ _______
Inventing packages of options to discuss _______ _______
Others (specify) ______________________________ _______ _______

If the New England project were to continue on a long-term basis, who would you trust to provide technical information and analysis for the group?
(5= 1st choice, 4=2nd choice, etc.)

University/Academic _______
Government Agency (specify) _______
NEPOOL Planning Staff _______
Other (specify) ___________ _______

Technical Expert/Consultant _______
National Laboratory _______
"Blue Ribbon" Committee _______
None _______

What are your greatest concerns regarding the feasibility of this planning process?
(Prioritize: 5=important,...4...3...2..., 1=unimportant)

Conflicting interests of parties ______
Differing perceptions of main issues ______
Conflicting technical information ______
Disparate values for non-dollar "intangibles"
(pollution impacts, catastrophic risks, etc.) ______
Polarization around different options ______
Uncertainty about the future ______
Unequal background/technical understanding ______
Consensus on lowest common denominator, not optimum ______
Others (specify) ____________________ ______

What analysis techniques would be useful in such a context?

for decision making: Cost-benefit analysis ______
Linear Programming ______
Multi-objective optimization ______
Multi-attribute / utility analysis ______
Other (specify) ______

for system simulation: Probabilistic production costing ______
Chronological production costing ______
Other (specify) ______

for demand modeling: End-use (bottom-up) model ______
Econometric (top-down) model ______
Systems dynamics (feedback) model ______

Have you participated in any other negotiated, or open planning process?

Negotiated ______ Collaborative ______
Open to Public ______ Other (specify) ______
None ______

If yes, how may I find out more about it? Contact name/phone/address ____________

____

What are your preferences?

Please prioritize the following issues.
(Prioritize: 5=important,...4...3...2..., 1=unimportant)

Cost of electricity ______
Environmental air quality ______
Quality / Reliability of electricity ______
Regulatory environment ______
Availability / ability to use new technologies ______
Other (specify) ______

What uncertainties concern you the most?
(Prioritize: 5=important,...4...3...2..., 1=unimportant)

Fuel price and availability ______
Load growth ______
Changes in demand and load shape ______
Changing environmental regulations ______
Technology availability ______
DSM impacts and effectiveness ______
Supply capacity performance ______
Investment costs ______
Other (specify) ______

What attributes are most important to you (considering the effects of uncertainty)?
(Prioritize: 5=important,...4...3...2..., 1=unimportant)

	Importance of average level of this attribute	Importance reducing variability in that level across different possible futures
Cost of electricity	______	______
Reliability	______	______
Environmental impacts	______	______
Investment levels	______	______
Fuel diversity	______	______
Other (specify)	______	______

Which demand-side strategies are the best ones for the region to follow?
(Prioritize: 5=best,...4...3...2..., 1=worst)

Utility-sponsored DSM ______
Energy efficiency standards ______
Tax credits for efficiency ______
Market-driven DSM ______
Other (specify) ______

Which supplystrategies are the best ones for the region to follow?
(Prioritize: 5=best,...4...3...2..., 1=worst)

Life-extend existing plants ______
Repower existing plants (higher efficiency) ______
Build new oil-fired capacity ______
Build new gas-fired capacity ______
Build new coal-fired capacity ______
Build new nuclear capacity ______
Purchase power from Canada ______
Other (specify) ______

Your job:

Electric Utility Management ______
Public Utility Regulator ______
Environment Department ______
Other Government
(specify) ______
Environmental Group ______
Industrial/Commercial
Electricity Consumer ______
Independent Power Producer ______
Other Energy Supplier
(specify) ______
Other (specify) ________ ______

Is this your first New England project Advisory Group meeting?

Yes ______

No ______

Your name (OPTIONAL): ________________________________

Please feel free to add any other comments you have on the back of this page.

Thank you for answering these questions. The results will provide guidance for dissertation research on ways to improve the analytics of electric utility open planning processes. Please contact me if you have any further insights that you are willing to share, or any questions.
– Clinton J. Andrews, Ph.D. candidate, Energy Laboratory, Room E40-481, M.I.T., Cambridge MA 02139. Telephone: (617) 253-7985.

APPENDIX C1: PARTICIPANTS' LIST FOR THE COM/ELECTRIC PROJECT

COM/Electric Open Planning Project Participants

Cambridge	Attendance Record				
	Accepted Invite	1st Meeting	2nd Meeting	Questionnaire	3rd Meeting
State Senator, Cambridge					
Facilities Manager (*attended New Bed.) Polaroid Corporation	√	√	√*	√	√*
Chairperson Neighborhood Nine Association	√				
President Dole Publishing					
Manager of Physical Plant Harvard University	√		√	√	√
Director of Community Relations Harvard University	√	√			
Chairman Cambridge Chamber of Commerce	√	√	√	√	
City Planner Community Development Department City of Cambridge	√	√			√
Energy Planner	√	√			
Associate Director of Physical Plant Massachusetts Institute of Technology	√	√	√	√	√
State Representative, Cambridge	√	√			
Chairperson Hastings Square Neighborhood Associat'n	√	√	√	√	√
Cambridge Totals	10	8	5	5	5

COM/Electric Open Planning Project Participants, cont'd.

Plymouth	Attendance Record				
	Accepted Invite	1st Meeting	2nd Meeting	Question-naire	3rd Meeting
Executive Director, South Shore Community Action Council	√				
Executive Director, Plymouth County Development Council	√				
Chairman/(Alt.-City Planner) Plymouth Board of Selectmen	√	(√)	(√)	(√)	
President MPG Communications (Newspapers)	√	√	√	√	√
President WATD Radio Station	√		√	√	√
Chief Executive Officer Cordage Park Company	√				
Representative Plimouth Plantation	√				
Banker, Plymouth	√				
State Representative (Alt.- Aide) Wareham	√	√	(√)	(√)	
State Representative, Plymouth					
President Plymouth Federal Savings Bank	√	√			
Selectman Board of Selectmen, Bourne					
Plymouth Totals	11	4	4	4	2

COM/Electric Open Planning Project Participants, cont'd.

Hyannis	Attendance Record Accepted Invite	1st Meeting	2nd Meeting	Question-naire	3rd Meeting
Speaker Assembly of Delegates Barnstaple County	√				
Executive Director (Alt.- Planner), Cape Cod Planning and Develop't Commission	√	(√)			(√)
President Cape Cod Hospital	√	√			
General Manager Cape Cod Mall	√				√
Executive Director Cape Cod and Island Board of Realtors	√		√	√	√
Owner Puritan Clothing	√	√			
State Senator, Hyannis	√	√			
Aide to State Senator, Hyannis		√	√	√	√
Publisher Cape Cod Times					
President Radio Station WOCB	√				
Executive Director Cape Cod Chamber of Commerce		√			
Executive Director Association for Preservation of Cape Cod			√	√	
President Cape Cod Bank & Trust Company	√	√			
County Commissioner Barnstaple County	√		√	√	√
Hyannis Totals	10	7	4	4	5

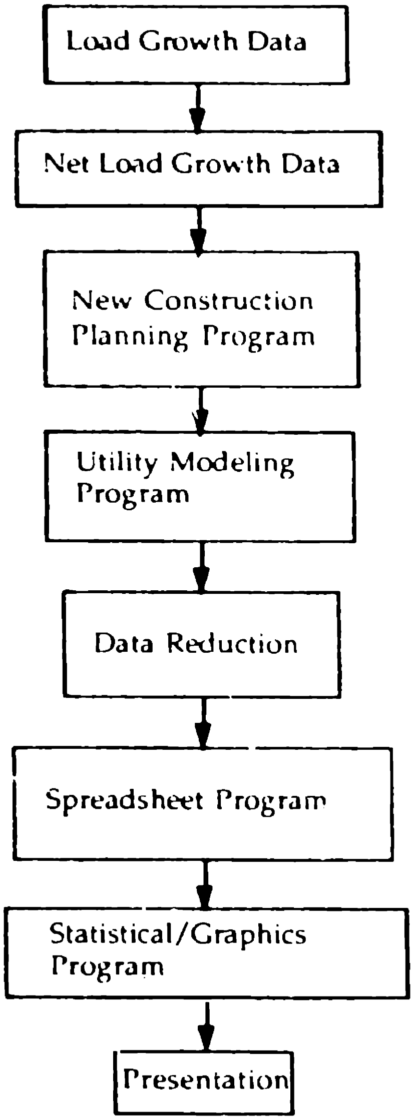
APPENDIX C2:
THE TECHNICAL ANALYTICS OF THE COM/ELECTRIC OPEN PLANNING PROJECT

COM/Electric Open Planning Project Participants, cont'd.

New Bedford	Attendance Record Accepted Invite	1st Meeting	2nd Meeting	Questionnaire	3rd Meeting
Editor New Bedford Standard Times	√			√	
Editor/(Alt.-Reporter) The Portuguese Times Newspaper		(√)			
President Acushnet Company	√	√	√	√	
Executive Secretary Fairhaven Town Hall	√	√		√	√
State Senator, New Bedford					
Manager, Public Works Department Town of Dartmouth	√				
General Manager Whaling City Cable TV		√	√	√	
President New Bedford Institution for Savings					
Chairman United Way of Greater New Bedford	√	√			
Mayor (Alts.- City Planners) City of New Bedford		(√)	(√)	(√)	
Chairman Bristol County Development Council	√	√			
Selectman Town of Freetown		√	√	√	
Owner/Editor The Cape Verdean Newspaper		√	√	√	√
Cranberry Grower		√			
New Bedford Totals	6	10	5	7	2
Anonymous				1	

This appendix is based on the COM/Electric LMSTM/Analysis Tutorial Handbook prepared by the Analysis Group for Regional Electricity Alternatives at MIT (1990). Principal authors were Daniel Greenberg and Warren Schenler. See the handbook for further details on the analytic process.

COM/Electric Scenario Analysis Process



Low, base, and high load growth projections are taken from Commonwealth Electric's load forecasting model

Conservation program impacts are subtracted from the raw load growth data to determine the net load the utility must meet.

This program simulates capacity addition decisions a utility planner would make over the course of 25 years to meet growing demand. Given the net load, the program determines when new plants should be built under each supply option.

A computer program called the Load Management Strategy Testing Model (LMSTM) is used to simulate each of the scenarios we study, producing information on utility operation for each year in the study period

Two more computer programs read through the LMSTM input and output files, pulling out results from each modeling run in raw form. Some calculation of the final attributes occurs here.

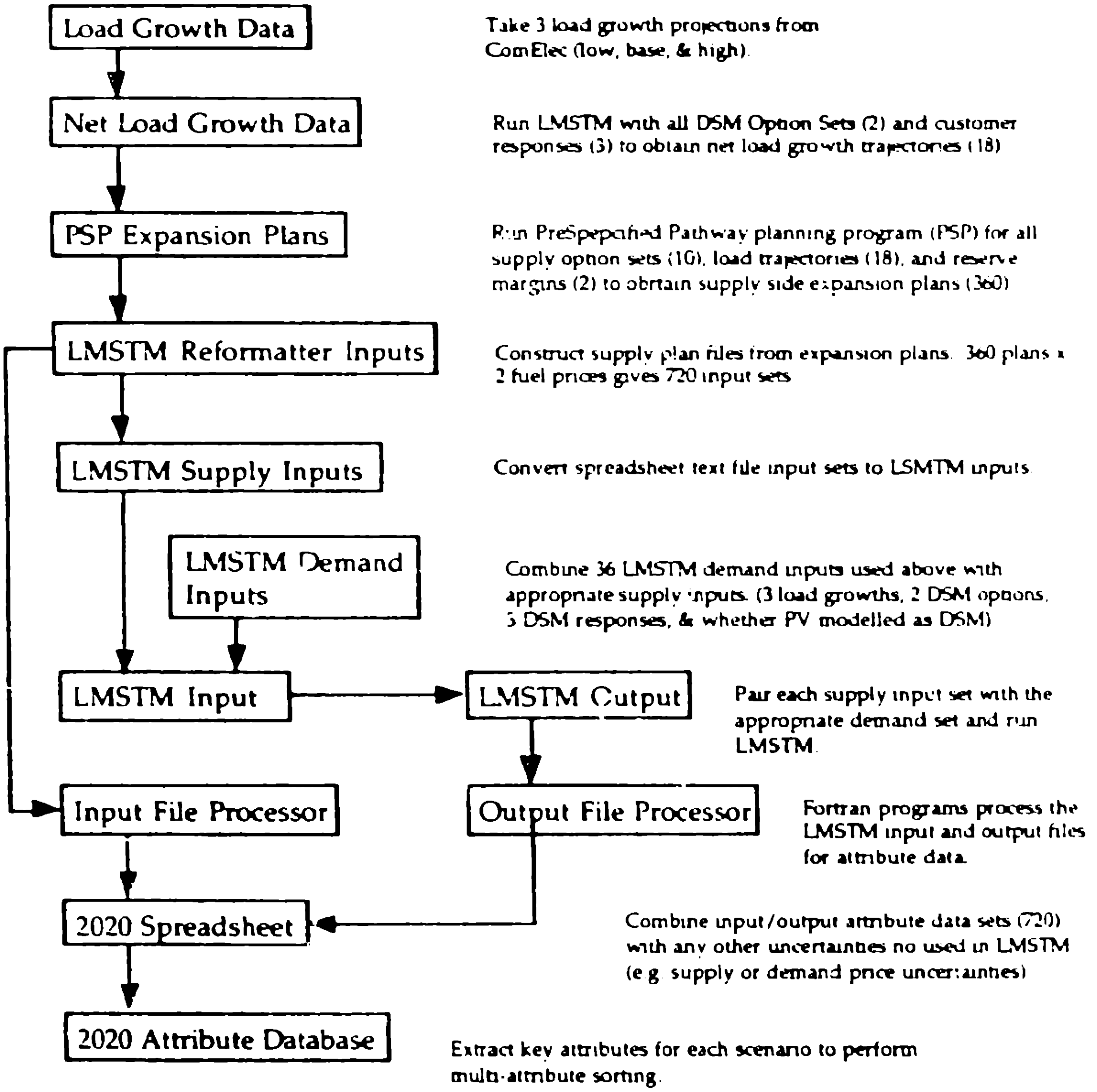
The extracted raw data is transformed into the attributes of interest here. For example, streams of annual SO2 emissions are converted into 25 year totals, and streams of utility costs are converted into present values

The final attributes are next analyzed statistically and graphically to determine the effects each of the options and uncertainties has on the attributes

The results of this analysis are summarized for consideration by the consumer advisory group.

The main simulation tool used for the COM/Electric project was LMSTM (Load Management Strategy Testing Model), a product of DFI/Electric Power Software. Several additional programs were written to make scenario analysis feasible. The stages in the run process are identified below. The following pages provide more details on each stage.

LMSTM Run Process



Take 3 load growth projections from ComElec (low, base, & high).

Run LMSTM with all DSM Option Sets (2) and customer responses (3) to obtain net load growth trajectories (18)

Run PreSpecified Pathway planning program (PSP) for all supply option sets (10), load trajectories (18), and reserve margins (2) to obrtain supply side expansion plans (360)

Construct supply plan files from expansion plans. 360 plans x 2 fuel prices gives 720 input sets

Convert spreadsheet text file input sets to LSMTM inputs.

Combine 36 LMSTM demand inputs used above with appropriate supply inputs. (3 load growths, 2 DSM options, 3 DSM responses, & whether PV modelled as DSM)

Pair each supply input set with the appropriate demand set and run LMSTM.

Fortran programs process the LMSTM input and output files for attribute data.

Combine input/output attribute data sets (720) with any other uncertainties no used in LMSTM (e.g. supply or demand price uncertainties)

Extract key attributes for each scenario to perform multi-attribute sorting.

LMSTM Demand Input File Blocks

Block A: Rate Class Information
- Rates not modelled, so entire load modelled as single rate class.
- Copied verbatim from COM/Elec Block A input.

Block B: System Load Information
- Hourly load shapes for four different day-types in each of four different seasons.
- Peak and energy escalation pattern ID's for each season/day-type.
- Hourly and daily demand elasticities (contained in demand forecast).

Block-C: DSM Technology Descriptions
- Technology name and type
- Utility/customer costs & cost-escalation patterns
- Energy savings per participant
- Distribution of savings by season/daytype
- Load Shape ID's (refer to block E)
- Trajectory of participants

Block D: DLC Technology Descriptions
- Refer to a DSM technology
- Hours of operation
- MW & kWh shifted per participant
- Real & "intangible" costs of technology

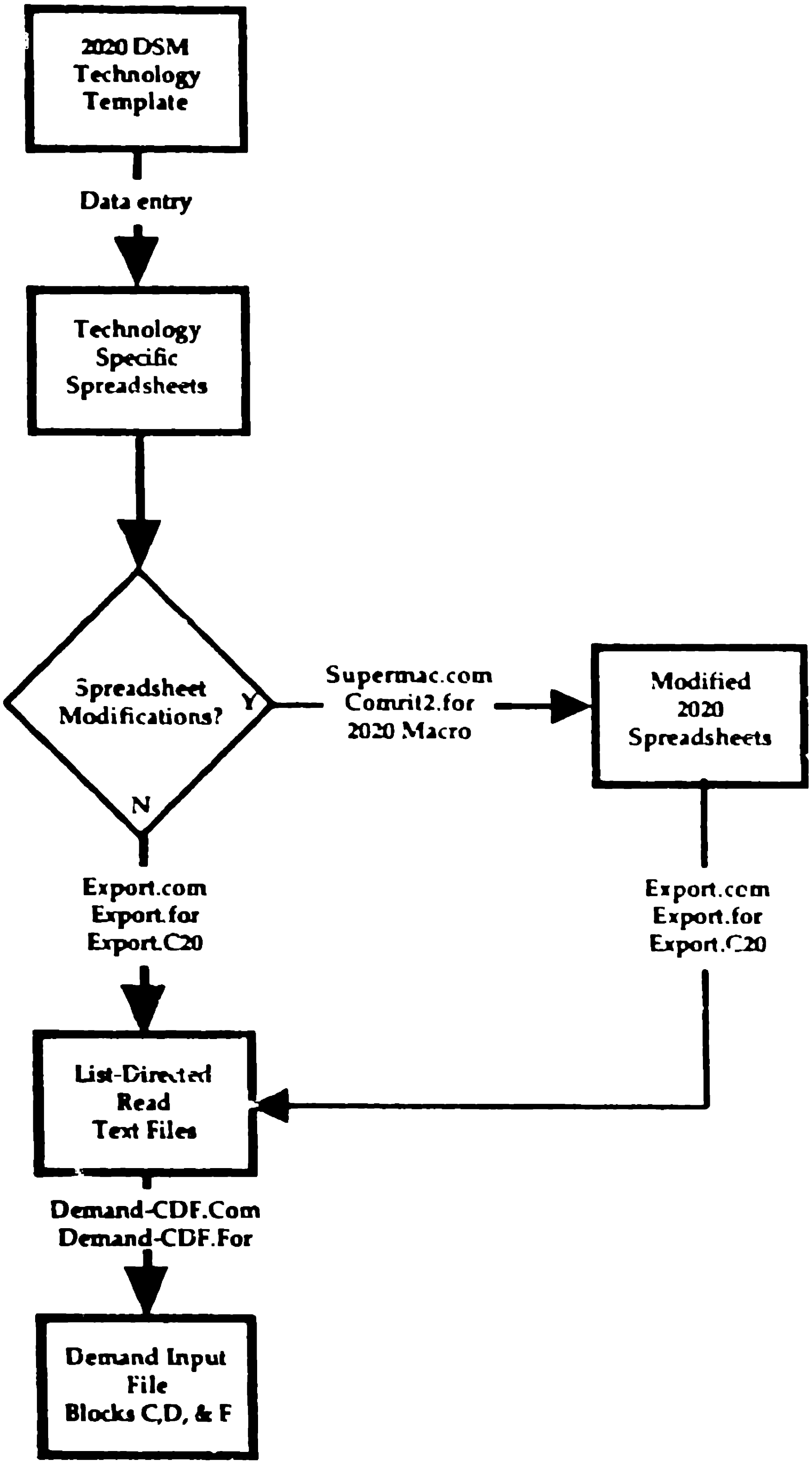
Block E: Load Shape Definitions
- Hourly relative load shapes by season/day-type for each technology (several are used by more than 1 technology).

Block F: DSM Program Evaluation
- Can group DSM techs into programs
- Discount rates for participants in each group
- Allows calculation of costs/benefits for each participant group

Block H: Peak and Energy Escalation Patterns
- Annual percentage increases
- Referenced by block-B

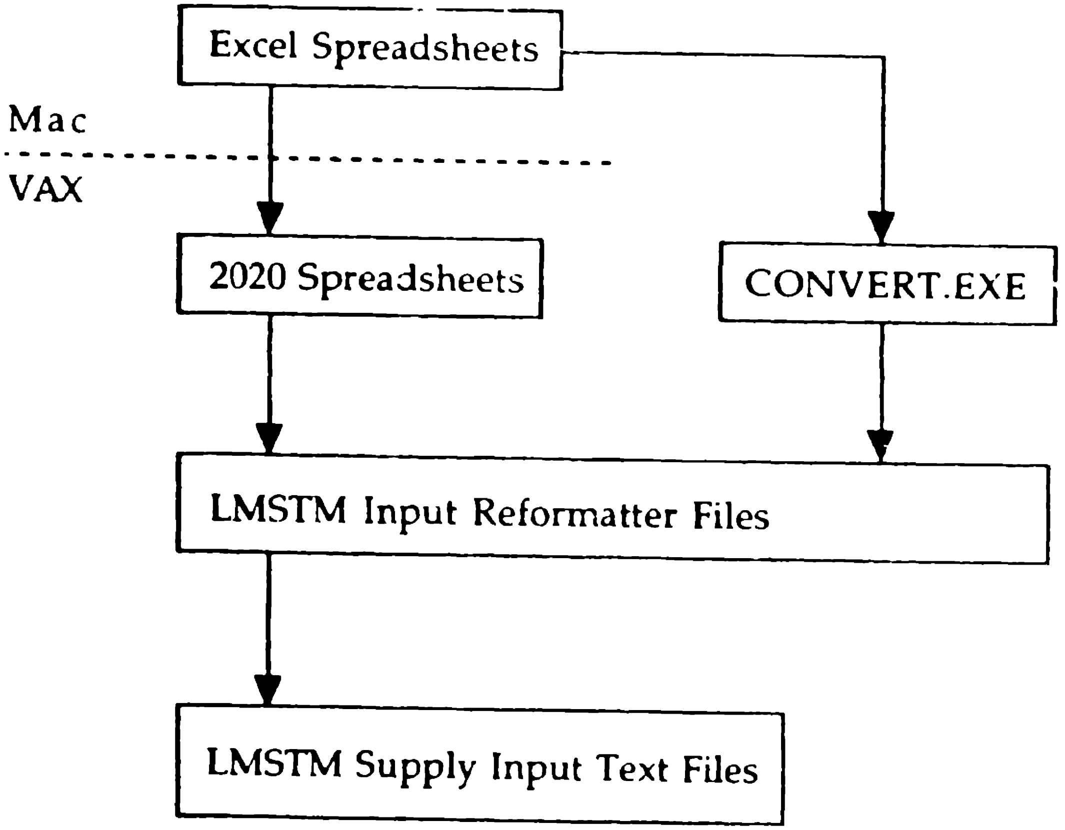
Block I: Cost Escalation Patterns
- Annual percentage increases
- Referenced by DSM techs, financial and rates submodels

Automated Construction of Blocks C,D, & F of the LMSTM Demand Input File

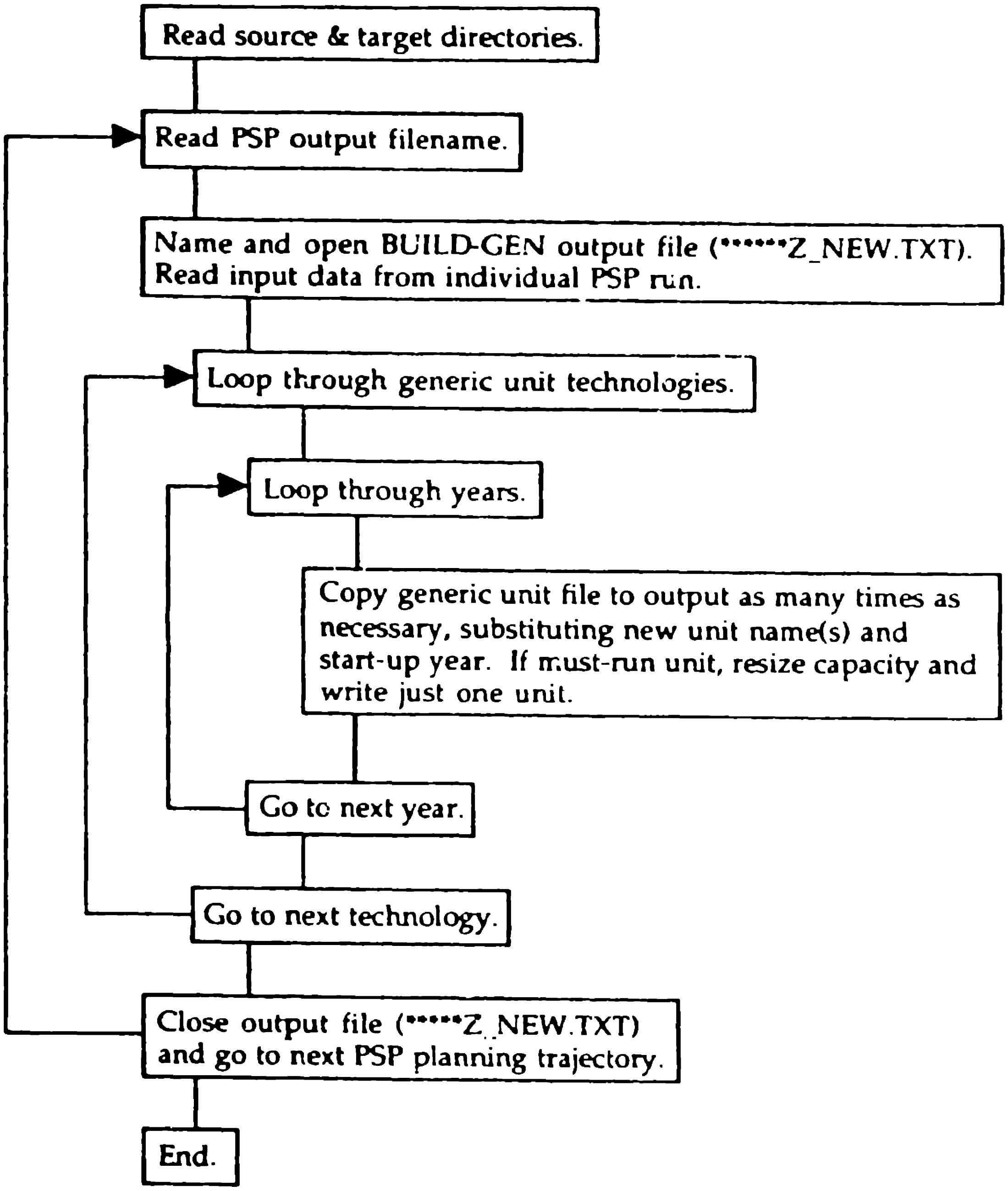


Supply data are initially entered into Macintosh spreadsheets. The PSP (PreSpecified Pathway) program described in Appendix B2 produces a supply trajectory based on the spreadsheet data. This information is then ported over from Mac to Vax, as shown below. Once there it must be reformatted into the relatively verbose LMSTM input format. The BUILD-GEN and COM-WRITE algorithms make this task simpler. Each is described below.

Supply Input File Transformations

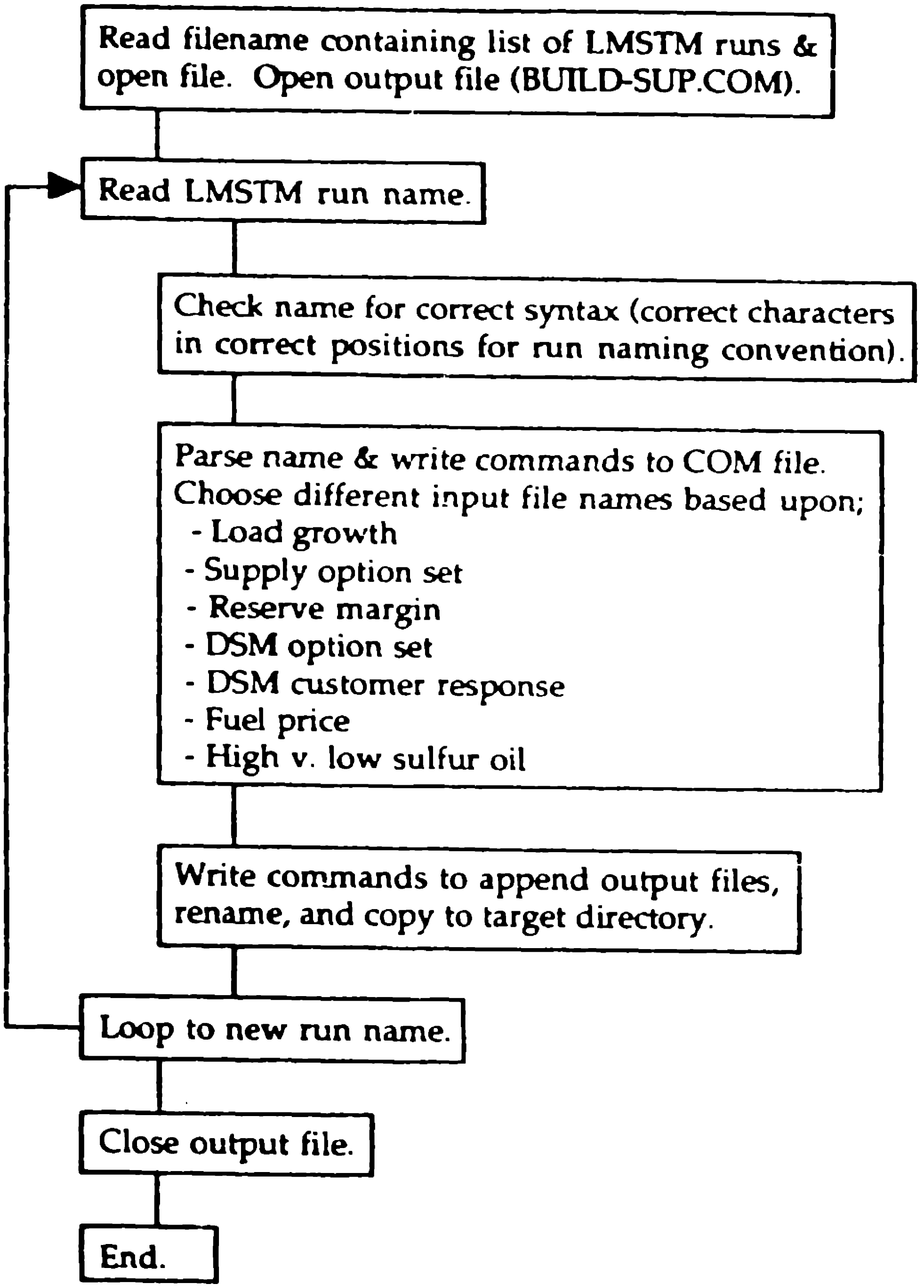


BUILD-GEN Algorithm Flowchart



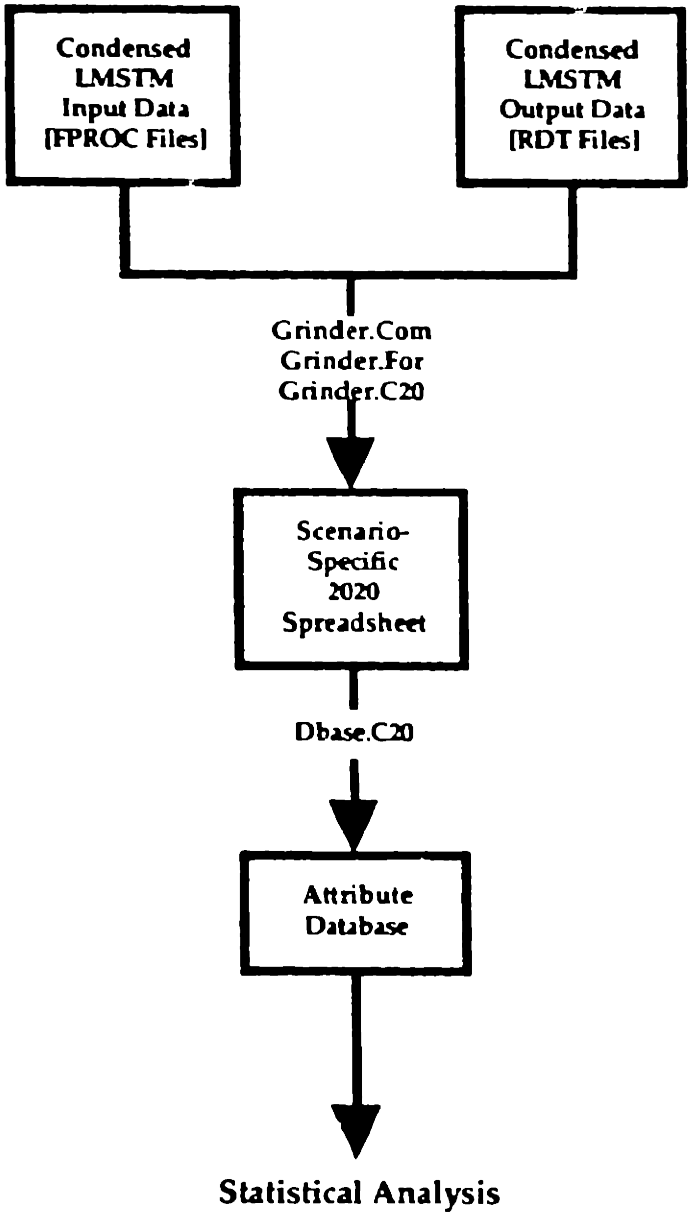
Note: BUILD-GEN allows for dual-fueled units, must-run units, and technology specific constuction delays

COM-WRITE Algorithm Flowchart

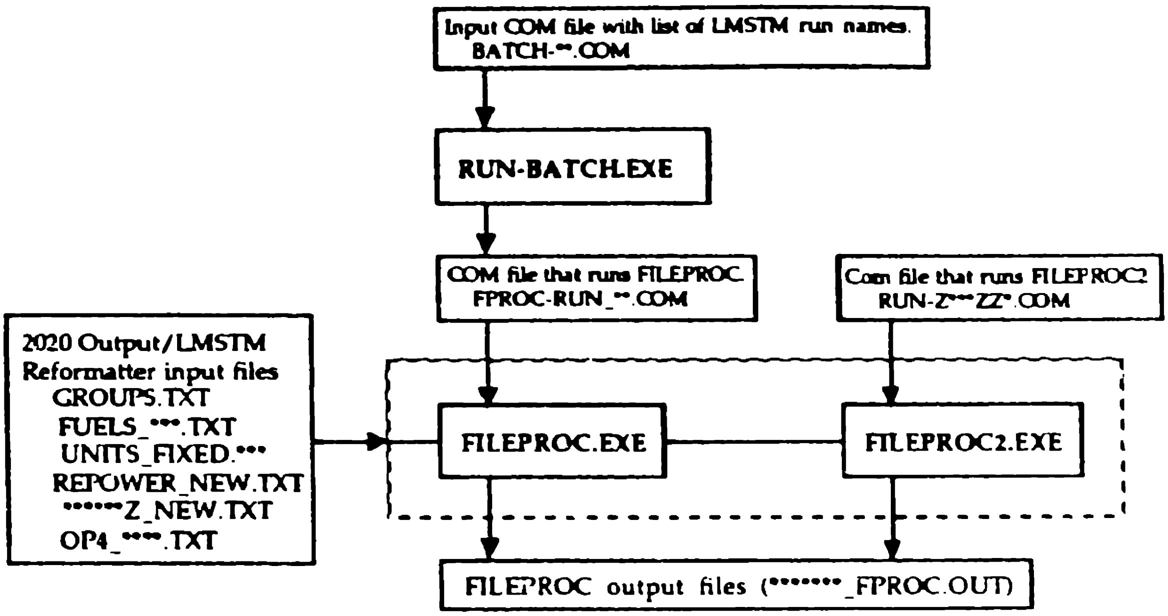


Attribute Processing Automation

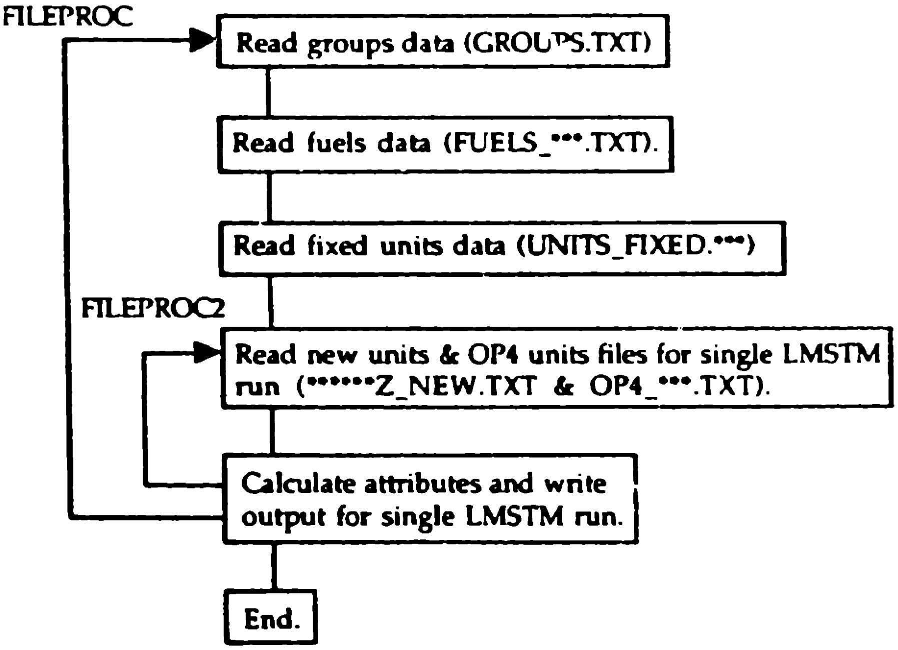
The output from the LMSTM runs is condensed into an attribute vector for each scenario using a series of Vax 2020 spreadsheets, macros, and Fortran programs. The major programs are described below.



FILEPROC Execution Flowchart



FILEPROC Algorithm Flowchart



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- (1990c) 1st Presentation to the Advisory Groups for the COM/Electric Open Planning Project, March;
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