ENERGY LABORATORY

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

ALTERNATIVE ELECTRIC GENERATION IMPACT SIMULATOR - Final Summary Report

James Gruhl, David Coate, Edmund Schweppe

Energy Laboratory Report No. MIT-EL 81-044
August 1981

ALTERNATIVE ELECTRIC GENERATION IMPACT SIMULATOR - FINAL SUMMARY REPORT

by

James Gruhl, David Coate, Edmund Schweppe
MIT Energy Laboratory

Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Sponsored By

Northeast Utilities Service Corporation
New England Electric System

Under the

M.I.T. Energy Laboratory Electric Utility Program

Energy Laboratory Report MIT-EL 81-044

August 1981

NOTICE AND ACKNOWLEDGEMENTS

This report was prepared at the MIT Energy Laboratory, Cambridge, Mass., as a summary account of the work performed on prediction of air pollution standards and strategies for meeting those standards. This research was sponsored by Northeast Utilities Service Corporation, under the principal direction of Denning Powell and with the assistance of William Renfro, and was sponsored by New England Electric System, under the initial direction of Bradley Schrader, and later Jack Walsh. The use or sponosrship of this program has begun in different related areas at E.P.A., E.P.R.I., and, in a major new effort, at D.O.E. This research was conducted as part of the M.I.T. Electric Power Program, William Hinkle, program manager.

ABSTRACT

This report is a short summary of three related research tasks that were conducted during the project "Alternative Electric Generation Impact Simulator." The first of these tasks combines several different types of investigations aimed at exploring the potential for, and significance of, uncertainty in the energy technology assessment process. A survey and discussion is presented of technology assessments, primarily from a methodological viewpoint. A general ideal methodology is developed and the potentials for incorporating uncertainties are described. There is particular emphasis on the impacts of assumptions and potential methods for incorporating concepts of uncertainty.

The implementation of an ideal assessment methodology resulted in the second task involving the coding of a simulator that should be viewed as a framework for assembling and manipulating information about the economics, emissions, ambient concentrations, and potential health impacts of different types and configurations of electric power generating facilities. The framework is probabilistic, and thus results in several measures of the range of various consequences, in other words a graphic display of the quality of the various predictions. The simulator is structured so that it is easy to improve the sophistication of certain manipulations, or to replace generic data, or update or add new data. The latest version of the simulator is available from the authors and can be operated in batch or interactive modes.

The third task involved the prediction of the ambient air quality

standards over the next thirty years. This was required in order to have benchmarks against which to compare the performance of facilities which are simulated in the task 2 simulator. This third task required the development of a standards prediction methodology through a modified Delphi-style survey of a large set of consultants.

In the face of a neverending battle to gather current data and update the computer codes, the material described in this report is of general interest. The annotated computer codes are available separately.

TABLE OF CONTENTS

1. INTRODUCTION

This project has involved a relatively small scale effort to conduct basic research followed by applied research in the area of air pollution control strategies and air pollution standards. Two undergraduates and two graduate students participated in a major way in this project. In addition to the expertise collected by these students, this project allowed Energy Lab personnel to gather experience in this energy/environment field, and several government and industry sponsored projects have resulted. Thus the output of this project consists of basic and applied research results, manpower training and developmental funds.

The performance period of this project has included a first phase conducted for one year from 1977 to 1978 and a second phase of a year ending in 1980. The work, however, has continued because the model in task 2 is constantly being modified and augmented and there is, of course, a persistent struggle to try to catch up with current data. In the face of this neverending battle it was decided that this report should contain the information of general interest that could be extracted from the work on the three tasks. Section 2 thus contains the general information excerpted from (Coate, 1980) on uncertainties in energy technology assessments. Section 3 contains general information about the AEGIS simulation model, excerpted from (Gruhl, Nov. 1978) and updated with brief descriptions of the later features added to the model. Section 4 excerpts information from (Gruhl, Sep. 1978) about the prediction of future ambient air quality standards.

2. UNCERTAINTIES IN ENERGY TECHNOLOGY ASSESSMENTS

In this study, "technology forecasting" will be included in the term "technology assessment."

Definition:

> Technology assessment is the process of taking a purposeful look at the consequences of technological change. It includes the primary cost/benefit balance of short-term, localized marketplace economies, but particularly goes beyond these to identify affected parties and unanticipated impacts in as broad and long-range fashion as possible. It is neutral and objective, seeking to enrich the information for management decisions. Both "good" and "bad" side effects are investigated since a missed opportunity for benefit may be detrimental to society just as in an unexpected hazard (Carpenter, 1973, p. 41).

Energy technology assessments are generally conducted using assumptions, methodologies, and data that can considerably bias the results. "Moreover, unless and until Technology Assessment is seen in a broader social and philosophic framework, it is bound to be a one-sided apologia for the prowess of existing technology. Genuine Technology Assessment must be essentially critical, not apologetic, with regard to technology" (Skolimowski, 1976, p. 421). Skolimowski says that technology assessments are done by technicians while paying lip service to "social aspects." He adds that "methodology takes precedence over values and we gently ride on the high horse of quantitative techniques toward the instrumental paradise" (ibid., p. 424). This point, that the assessing of a system should be done by those outside of the system to remain unbiased, is difficult to achieve in practice because those with expertise about technologies will naturally have invested considerable personal resources in those technologies and thus will tend to have optimistic biases.

It is clear that either faulty assumptions, methodologies, or data can propound error. "Methodology expresses (and traces the implications of) core assumption reflecting the forecaster's fundamental outlook. Sophisticated methodology cannot save a forecast based on faulty core assumption" (Ascher, 1979, p. 149). William Ascher stresses the importance of the assumptions compared with methodology: "The development of greater methodological sophistication has not significantly improved forecast accuracy. The (often [greater than] linear) deterioration of accuracy with lengthening of forecast time horizons proceeds regardless of method" (ibid., p. 149). However, the complexity and large data requirements for a methodology are not inherent in the methodology. "It is the real-world situation and not the methodological analysis which presents the complex interrelationship and the necessity of a large data pool. No model nor methodology can greatly simplify a complex situation without losing some validity" (Bareano, 1972, p. 189).

It is instructive to compare technology assessments conducted by institutions with the differing special interests of those institutions. A university study done from a national point of view would likely have a different goal orientation than a corporation or private interest (Humes, 1974, p. 145). Also, assessments may be undertaken to gain support for a favorite project or decision already reached. "Thus it is important to know not just how a forecast was made, but why it was done as well, in evaluating its worth" (Kiefer, 1973, p. 140). These considerations are the motivation for this study, which includes a systematic investigation to determine the areas and extent of biases in energy technology assessments. Both methodological and data biases are evaluated, primarily through the use of equally defendable or superior alternative methodologies or data.

2.1 Historical Perspective

It is interesting to look at past technology assessments in order to see what not to do. History provides us with many examples of technological innovations that were total failures simply because of incomplete technology assessments. Many of these past technology assessments "...have been undertaken in response to a specific problem created by the introduction of new technology into society, rather than in anticipation of innovation... Assessment in the past has often been on a trial-and-error, hit-or-miss basis, with little perspective beyond short-term hazards, opportunities, and alternatives. It has viewed the future narrowly--if at all--as no more than an extension of the immediate past" (Kiefer. 1973, p. 137). Looking back 75 years, experts might have predicted that a gasoline-powered machine would replace the horse-drawn vehicle. But it is unlikely if they could have anticipated that the automobile would be directly responsible for one out of every seven jobs, that it would kill 60,000 U.S. citizens each year, and that it would cause significant impacts on public health via the emission of harmful air pollutants (Jones, 1973, p. 143).

Clearly, we are idealistic and naive if we suppose every nuance of a future technology can be predicted. "To use a historical example, it is doubtful that, given the time and manpower..., we could have predicted the contribution the elevator would make to traffic congestion in cities (assuming continued reliance on individual transit). It is these highly indirect impacts which are, of course, the hardest to foresee and which sometimes have the most far-reaching effects upon the society. They usually become evident only after prolonged experience with the technology..." (Humes, 1974, p. 156).

No technique of assessment can really envision the flashes of innovation or the unpredictable discoveries which lead to great technological change. The occurrence of technological breakthrough really cannot be predicted. For example, an aircraft industry researcher of the 1940s would have predicted the maximum air speed of a prop plane based on the theoretical limit being the speed of sound. He could not take into account the advent of the jet engine.

Another great deterrent to technology assessment is technological dependence upon sociopolitical influences. "The fundamental difficulty in foretelling social and political change--or of even divising meaningful social indicators for measuring such changes statistically--remains a serious obstacle not only for technological forecasting but for technology assessment as well" (Kiefer, 1973, pp. 139-140). Value systems of society and political authorities are hard to define, and even harder to describe how they will change with time.

2.2 Alternative Methodologies

There are numerous methodologies for technology assessment. Some may work better than others but still depend heavily on the core assumptions. The Delphi technique "...is designed to apply the collective expertise and intuition of a panel of anonymous experts by developing a consensus through several steps of systematic questioning and polling about future events. The polling process is carefully organized so as to minimize the biases that might otherwise arise from interacting personalities or other psychological influences within the expert panel" (ibid., p. 138). Delphi techniques work best when historic data are unavailable, sociopolitical considerations are needed, or qualitative or subjective information is necessary.

Other methodologies including parameter-fitting, curve-fitting, and structural-fitting are used when the appropriate data are available. A refinement of curve-fitting is the envelope curve technique (Kiefer, 1973, p. 138). A general curve is superimposed to a number of specific curves. For example, the maximum speed of transportation could be forecasted by superimposing a curve onto specific historical data of various modes of transportation. Curve-fitting is based on the assumption that there are predictable trends in the manner in which "...the technology that will be put in use tomorrow is foreshadowed by the science of today or is a direct outgrowth of current technological knowledge" (ibid., p. 138).

Other techniques include the jury system, market system, cost-benefit analysis, and adversarial processes. The adversarial process facilitates the articulation of all relevant facts both pro and con. Unfortunately, this and other assessment methodologies, are particularly susceptible to the biases in the situation where the proponents of a technology have an advantage over the opponents because of organizational and financial resources. This is when technology assessment becomes "...slanted in a subtle and often an explicit way in favor of the assumptions underlying the technological civilization, of which it is supposed to be an assessment" (Skolimowski, 1976, p. 422).

Figure 1-1 shows a generic seven-step methodology laid out by MITRE (Jones, 1973, p. 148). This scheme illustrates how assumptions are built into a methodology. Usually, the assumptions are not quite as evident.

Weighting schemes are frequently used in technology asessments, probably because of their easy implementation and easy interpretation. For example, one methodology computes a score for a technology and allows comparisons of technologies by comparing scores (Humes, 1974, p. 152). The weights are assigned by a panel of "experts" and thus the scheme is essentially subjective. "Even with detailed printed instructions, examples and close supervision, it is impossible to enforce consistency of interpretation and scale on a group of diverse individuals on the first round of assessments" (ibid., p. 154). There is nothing wrong with this type of subjective assessment, except that the highly quantitiative methodology sometimes presents the appearance of greater objectivity than is warranted.

An intuitive, hence subjective, method is scenario writing: "A scenario attempts to describe, in systematic but hypothetical and largely qualitative terms, the future sequence of events that would appear logically to evolve, step by step through cause-and-effect relationships, from any given set of conditions or recognized trends. Enphasis is placed on those critical decision points from which alternative chains or events might arise and on the simultaneous

STEP 1	DEFINE THE ASSESSMENT TASK	
	Discuss relevant issues and any major problems Establish scope (breadth and depth) of inquiry Develop project ground rules	
STEP 2	DESCRIBE RELEVANT TECHNOLOGIES	
	Describe major technology being assessed Describe other technologies supporting the major technology Describe technologies competitive to the major and supporting technologies	
STEP 3	DEVELOP STATE-OF-SOCIETY ASSUMPTIONS	
	Identify and describe major nontechnological factors influencing the application of the relevant technologies	
STEP 4	IDENTIFY IMPACT AREAS	
	Ascertain those societal characteristics that will be most influenced by the application of the assessed technology	
STEP 5	MAKE PRELIMINARY IMPACT ANALYSIS	
	Trace and integrate the process by which the assessed technology makes its societal influence felt	
STEP 6	IDENTIFY POSSIBLE ACTION OPTIONS	
	Develop and analyze various programs for obtaining maximum public advantage from the assessed technologies	
STEP 7	COMPLETE IMPACT ANALYSIS	
	Analyze the degree to which each action option would alter the specific societal impacts of the assessed technology discussed in Step 5	

Figure 2-1 Various Stages in the Process of Technology Assessment

interactions between events and their environment. A single set of assumed initial circumstances can generate an entire family of related scenarios (or alternatively futures), any one of which may be plausible" (Kiefer, 1973, p. 138).

"Normative" forecasting starts with some future need "...and attempts to work backwards in time toward present capabilities so as to define the technological pathways and means by which a goal might be reached and to identify the technological barriers which must be overcome in the process. The aim is less to prophesy than to "invent" the future, with the focus not on that which might happen but on that which should happen" (Kiefer, 1973, p. 139). It is clear that such an analysis can be highly subjective and rests on such assumptions as unchanging social values.

The role of methodology in technology assessment should be as a thinking and decision making tool. Assumptions and qualitative aspects inherent in the methodologies should be viewed as flaws and pointed out clearly. If the public is going to take technology assessment seriously, especially in the controversial area of energy, current methodologies and reporting techniques will have to change.
"Forecasters frequently seem more enthralled with the entertaining tasks of model building, manipulating and massaging series of data, and imposing some sort of formal stylized structure on the seemingly random process of scientific discovery and technological innovation than they are with the more mundane chore of explaining to the world outside what their studies and speculations are all about or how they might find

practical application. Increasingly sophisticated and complex methodology may appear designed, as a result, less to make forecasting more reliable and rational than to conceal its shortcomings and veil its relevance to the world at large" (Kiefer, 1973, p. 140).

2.3 The Role of Uncertainty

Uncertainties in technology assessments become very important when comparing different energy technologies. Many uncertainties are beyond the scope of a technical assessment, for example, those uncertainties that result from national priorities shifting substantially over short intervals. Such a shift within our recent experience is the fast-rising concern over energy issues, at the expense of a rapid deemphasis of the space program.

There are, fortunately, many uncertainties that are amenable to treatment within current technology frameworks. Where the accuracy of forecasts often deteriorates linearly with time, one can set rough confidence intervals. Also, much can be done to use data that is as current as possible. Using outdated data propounds error unnecessarily. But there is "...uncertainty as to whether recent data actually represent a new pattern that negates the old assumption" (Ascher, 1979, p. 152).

Probably the greatest uncertainty in technology assessment, and the hardest one to reduce, is due to sociopolitical factors. The nuclear power industry is a good example of this. "The greater uncertainty in forecasting technological developments requiring political decisions and large-scale programs indicates the importance of improving sociopolitical analysis. The social indicators and scenario approaches are two means for achieving this improvement" (Ascher, 1979, p. 149)

William Ascher lists three types of uncertainties in technology assessment in order of increasing uncertainty (Ascher, 1979, p. 153):

I. Smallest disperson: Technological areas in which advancement depends on engineering refinements and the disaggregated market diffusion of such innovations.

II. Less certainty: For predictions of advancement in large-scale programs, the political aspect adds an additional degree of uncertainty to that already surrounding the technical feasibility of the programs.

III. Most uncertainty: innovations requiring basic scientific breakthroughs.

2.4 Assessment Methodologies and General Assumptions

In technology assessment the methodologies and the assumptions are usually so intertwined that it is not possible to discuss them separately. Since the methodology can be viewed as the framework of the assessment, as well as the vehicle of the principal assumptions, the alternative methodologies will be treated first.

It is an extremely difficult task to try and characterize the range of all possible energy technology assessments. Part of this difficulty is due to the scattering of the methodologies into apparently every possible analytic direction. The rest of the difficulty stems from the lack of any real formalism to the modeling science. As an attempt is made here to develop some of this formalism. Figure 2-2 illustrates a schematic diagram of a proposed methodology that includes all the desirable qualities in an energy technology assessment. One possible starting point for the discussion of methodologies comes from the natural origin for all modeling activities: a definition of objectives. "It is difficult to to make a simple statement of the purpose of integrated assessment; there is a hierarchy of objectives, and the order will change with time and will contain hitherto unknown dimensions. Broadly speaking, there is a need for the timely development of relevant knowledge and its diffusion to a broad audience -- but especially to the general public, regulators, scientists, and engineers" (Gruhl, 1979). The research and academic communities for generally responded to these needs by identifying complex energy technology assessment methodologies, with few actual applications.

> Modeling undertaken in an application-oriented, integrative context (i.e., the synthesis and integration of current knowledge) has a better chance of facilitating decision making than modeling undertaken as basic research. This is not to belittle the role of basic scientific research, but to suggest that modeling must be undertaken with different and perhaps more pragmatic objectives (SCOPE, 1976).

From an examination of the literature it appears that another natural starting point in the investigation of a technology assessment comes from the data used to characterize the Performance Measures of the Technologies, as shown near the center of Figure 2-2. There are two types of assumptions that pervade the choice of these performance measures. First is the Value System used by the assessor/modeler. Few authors of the assessment literature have reorganized the inherent bias in the <u>types</u> of performance informations that are collected about the technologies. The principal focus of the capabilities of a model is

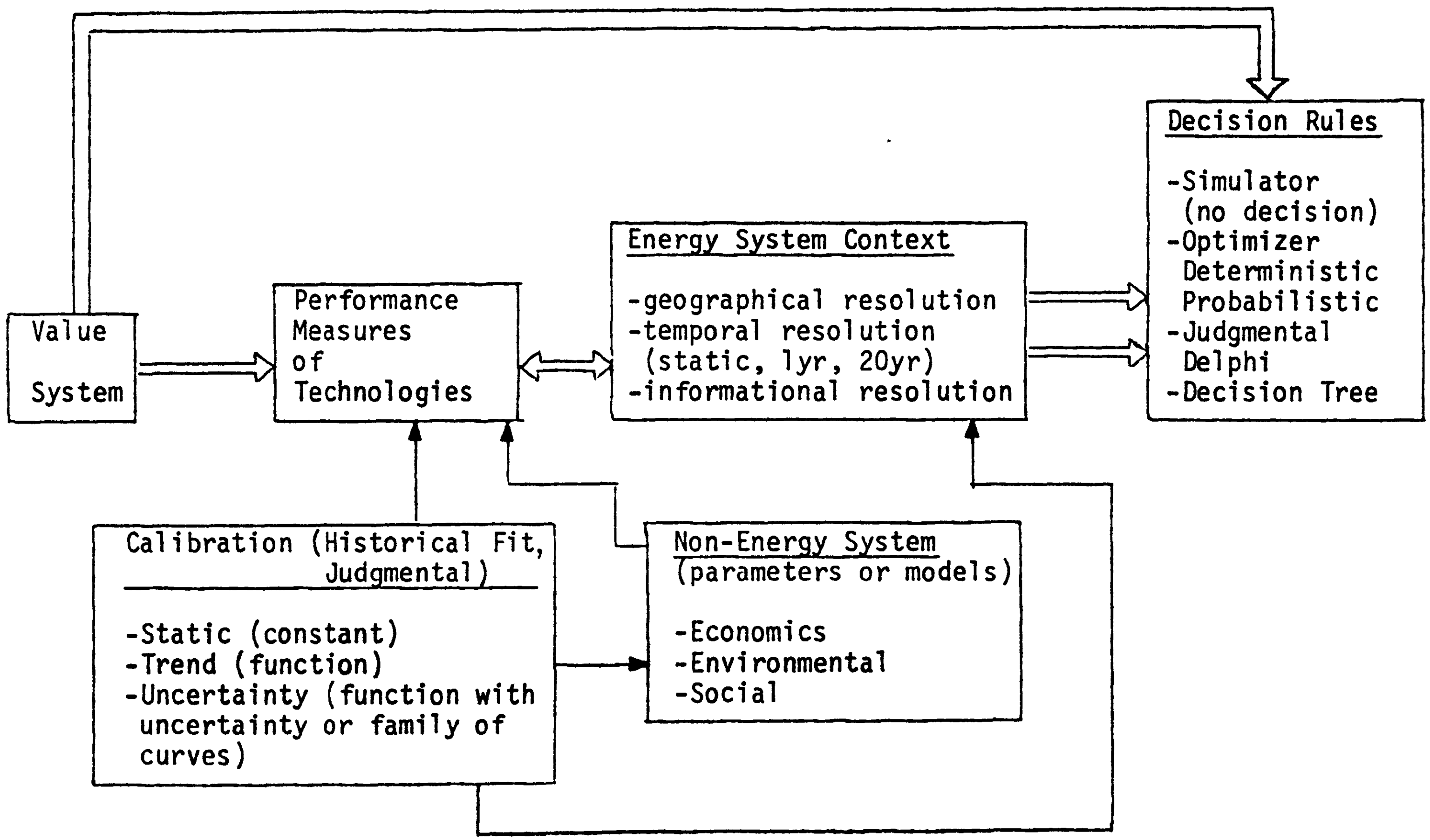


Figure 2-2 General Methodological Framework for Energy Technology Assessments

fixed at the point when data is collected about the technologies. The academic and professional backgrounds of modelers also bias the modeling procedure at this stage, due primarily to familiarities with sources and techniques for handling certain types of data. It would be instructive for modelers to begin their modeling activities by stepping back and taking a global perspective to their assessment problem, and documenting the motives for including or excluding data of certain types such as data types listed in Table 2-1.

The second assumption of great importance to the performance characterization is the extent to which the performance measures are coupled to energy system requirements. The most simplistic technology assessments just provide evaluations of performance that are not in the context of the specific needs of the energy system. Whether the technology is to be added to some local area, or to be added massively nationwide, it can be the most dominant part of the assessment to evaluate the manner with which that technology can both respond to the peculiarities of the other energy supply sources. Recognizing this need, several modelers have provided coupling of the performance measures and the energy system, again as shown in Figure 2-2. Of lesser importance, from the standpoint of energy technologies, is the extent of coupling of the non-energy system to both the energy system and the performance measures (e.g., might there be rate-constraints on the availabilities of certain materials or manpower). The method, format, and data used for the construction and <u>calibration</u> (also shown in Figure 2-2) of the performance measures, energy system model, and non-energy

Table 2-1

SOME OF THE VARIOUS DISCIPLINES
THAT HAVE BEEN ASSOCIATED WITH ENERGY RESEARCH (Gruhl, 1979)

Economics

Policy Analysis

Decision Analysis

Operations Research

Management

Law

Institutional Analysis

Energy Planning

Energy Engineering

Analytic Chemistry

Seismology

Mining

Transportation

Atmospheric Dispersion

Hydrology

Waste Management

Land Management

Ecology

Environmental Management

Health Studies

Psychology

Sociology

Demography

Urban Studies

system model, provides another key difference between various energy technology assessments. The concept of uncertainty could generally introduce itself at this calibration stage, being represented by probabilistic characterization of inputs and parameters in the assessment models.

For some reason the Decision Rules portion of Figure 2-2has presented the principal preoccupation of technology assessors. Perhaps it is because it is usually the non-engineers that conduct assessments and the Decision Rules segment represents the primary part of the assessment that does not deal with engineering problems. Table 2-2 (Gruhl, 1979) shows many of the modeling technologies currently available and it can be seen that any of these can probably be used to capture the essence of the decision rules.

Again as shown in Figure 2-2, the Value System, or the manner of measuring desirability, of the modeler will impose itself strongly on the selection of the Decision Rules. Even for models that do not include decision logic, there are value systems implicit in the types and displays of outputs. Some value systems that have been used in energy/environmental models include:

- o Bureaucratic (exhaustive) display,
- o Noninferior sets,
- o Multiattribute decisions,
- o Infinite value or uncompromised protection,
- o Cost-benefit or economic optimum, and
- o Surrogate indexes or weighting schemes

Table 2-2

Methodologies Available for Representing the Decision Rules for a Technology Assessment

Static Optimization

- o Linear Programming
- o Nonlinear Programming
- o Integer and Mixed-Integer Programming
- o Gradient Searches

Dynamic Optimization

- o Dynamic Programming
- o Dynamic Parametrics
- o Optimal Control
- o Stochastic Optimization
- o Algorithmics

Simulation

- o Descriptive, Prescriptive
- o Holistic, Causal, Normative
- o Continuous, Discrete
- o Stochastic Representation
- o Parametric Analysis
- o Allocation and Equilibrium
- o Input/Output
- o Econometric, Trend Analysis
- o Regression
- o Organizational Modeling
- o Interpretive Structural

Nonmodeling

- o Judgment Eristics
- o Expert Opinions
- o Hedonic
- o Decision Analysis
- o Individual Behavior
- o Bidding and Simulation Games
- o Cross-Impact and DELPHI

In addition, each of these systems can be operated with or without explicit quantifications of the risks involved in the decision-making process. The obvious problem with value systems is that impacts not predicted by the model will carry no weight in the model's decisions. Extremely important issues such as stability of the establishment, survival of the private electric power sector, or intergenerational equity therefore generally are not considered in models because vulnerability to foreign disruptions, infrastructure problems, intervenor effects, and public perceptions of problems are not included in model outputs.

Despite the obvious importance and uncertainty inherent in the Value System, we found no models that offered alternative system nor discussed the biases of the system presented. In an assessment it would seem to be very important to be able to separate the "value judgments" from the methodology. An assessment technique will not be useful if the user cannot use his own value system or clearly see the author's.

L. Thiriet urges the use of caution when dealing with quantified sybjective judgments: "We feel that one's first concern should be to make the method used acceptable both to the authorities and to the public. (We think the influence of the public should probably only increase in the future). One should therefore avoid resorting to too hermetic a language, using a too complicated system of notations, aggregation, evaluation of probabilities. This would save one from the temptation of believing in the rationality of choices in the field of environment, when these contain an irreducible and very important part of non-rationalizable elements. Moreover, the results of such a sophisticated study would not convince the public" (Thiriet, 1974, p. 230). L. Thiriet prefers a study that "...avoids all quantitative value indicators which would risk letting the reader in a hurry believe in a rational and scientific estimation. It should, on the other hand, suggest options judged preferable to others by arguing -- one might also say by pleading -- in a sufficiently detailed manner to allow the authorities to make their decision by the light of a clearly expounded document" (Thiriet, 1974, p. 233).

2.5 Imbedded Assumptions

Ascher points out the importance of assumptions: "It must be recognized that behind any forecast, regardless of the sophistication of methodology, are irreducible core assumptions representing the forecaster's basic outlook on the context within which the specific trend develops. These core assumptions are not derivable from methodology; on the contrary, methods are basically the vehicles, or accounting devices, for determining the consequences or implications of core assumptions that were originally chosen more-or-less independently of (and prior to the method)" (Ascher, 1979, p. 150).

Ascher states that forecast accuracy is dependent on the core assumptions and the methodology is obvious or secondary when the assumptions are valid. A methodology cannot redeem a forecast based on faculty core assumptions. One source of faculty assumptions is due to the specialization of most forecasters. Obsolete assumptions are sometimes used unknowingly due to the forecaster's specialization and the broad context of the assessment. This is why a panel of experts can be so effective for interdisciplinary technology assessments.

"Since the choice of methodology, which largely determines the cost of the study, is not as crucial to forecast accuracy as is the appropriate choice of core assumptions, recent inexpensive studies are likely to be more accurate than older, elaborate expensive studies. ...multiple-expert-opinion forecasts, which require very little time or money, do quite well in terms of accuracy because they reflect the most up-to-date consensus on core assumptions. When the choice is between fewer expensive studies and more numerous, up-to-date expensive studies, these considerations call for the latter (Ascher, 1979, p. 152). More emphasis should be placed on establishing core assumptions and testing their validity.

In most energy technology modeling a deterministic approach is used. This study contends that there are often unacceptable and unnecessary assumptions involved in such an approach. A probabilistic approach would be inherently less biased and the appropriateness and difficulties of its use will be discussed. In addition, in the use of nonlinear models, deterministic approaches may have significant errors even with respect to expected values. When the inherent risk aversion in the energy decision process is also factored in, it should be clear that deterministic approaches must be very crude or inappropriate.

Another caution in using probabilities in technology assessments is "Maintaining uniformity and consistency of interpretation...; it is the great weakness of methods based on quantified subjective judgments" (Humes, 1974, p. 152).

A major advantage of a probabilistic scheme would be in dealing with a complex model with many inputs. For example, it seems clear that decisions based on multiplying probabilities (assuming independence of parameters) would be inherently less biased than decisions based on a complex document stating all the relevant issues. It would have to be made clear how the probabilities were arrived at and any uncertainty in independence of parameters would need to be discussed. Another advantage of a probabilistic scheme is the ability to quantify uncertainty. Thus uncertainties could be traced through the model, and proper attention could be focused on parameters needing most reduction in uncertainty for decision making and R&D planning.

Energy decisions are inherently risk aversive due to the inelastic demand for energy and the long time lags associated with increasing supply. However, most technology assessments use deterministic approaches which lead to the use of an expected value in fuel pricing, supply, etc. But the use of an expected value is at best only appropriate in a risk neutral analysis. Thus, for energy analysis, a probabilistic approach would be much more appropriate due to the availability within such an approach of the capabilities for incorporating inherent risk aversion.

Another imbedded assumption in most technology assessments is the level of detail or resolution at the decision points of the model. This resolution is of three types:

(1) geographic

(2) temporal, and

(3) informational.

The first two types of resolution are quite obvious. It may be less obvious that models may work at two or more levels of resolution, performing computations at one level of resolution, then aggregating those results to yield outputs or information for decisions at broader levels of aggregation. Informational resolution is the final type of detail that will be mentioned. Aside from the disciplines that are included in a model's methodology, the model builder is faced with myriad decisions and implications concerning the types of information that are carried in model components and linkages. Unfortunately, three of the principal criteria used for the selection of information to be incorporated are: 1) availability of data, 2) computational burden, and 3) the degree of amenability of this information to the chosen modeling methodology. Ideally the criterion for selection should be the information's relative importance to the policy applications of interest.

2.6 Review of Assessments and Conclusions

In this study, a systematic investigation was made of energy technology assessments to evaluate their effectiveness. Most of the assessments studied contained significant flaws in assumptions, methodologies, and/or data bases. In addition to assumptions usually being hidden in the methodology, most technology assessments were biased in some way because of special interests. Such a biased approach is not "wrong", it is just inappropriate not to have the assumptions and interests of the assessor pointed out clearly so that the biases can be separated from the assessment. Even though probabilistic assessments have potential problems in implementation and interpretation, their use in a complex analysis seems more appropriate than the use of a deterministic approach.

Meteorological factors must be considered to address specific power plant siting problems. A technology assessment that applies national average meteorological characteristics to a specific site will most likely be biased against the fossil-fueled technologies. A much more accurate analysis would result by capturing the characteristics of the specific meteorological conditions at specific sites.

Atmospheric transport and dispersion modeling used in technology assessments are generally very inaccurate. It seems clear, from the studies reviewed, that the simplifying assumptions used make the pollutant concentration estimates too crudely. What is needed is an uncertainty bound rather than a specific value. In that way, models using dispersion results (e.g. health models), would be much more useable in the policy environment. It is difficult to have confidence in health model results, for example, when the dispersion model used is known to be inaccurate but does not give uncertainty bounds.

Populating densities and locations must also be carefully characterized to properly address specific power plant siting problems. An ideal specific siting analysis would include specific meteorological, and specific population data as well as including an uncertainty bound on the dispersion modeling results. In large scale technology assessments where it would be inappropriate to model all available sites, it would seem to be important to have several categories of generic sites for use in the analyses.

Current health modeling contains many more uncertainties than any other portion of the technology assessment process. However, health model results are used for policy decisions, many times with little knowledge of the uncertainty. Of the 255 health impact articles surveyed the majority showed that there was no impact on health from community air pollution levels. Furthermore, some of the articles showed beneficial effects of air pollution. Most of the 30 models available in that literature showed severe data and statistical problems. It seems apparent that the health impacts that have been used in past technology assessments can at best be construed as slight hints of what might possibly be the worst case health impacts. At worst these estimates are misleading and their use is counterproductive in the assessment process. It seems clear that adequate measures of the uncertainties in these models would be extremely important for conveying the levels of speculation associated with any numbers that are turned over to the policy decision process.

R&D priorities should be set up in such a way so as to reduce the uncertaint y in energy technology assessments. Obviously, where the greatest uncertainty lies and where this uncertainty crosses over into critical decision areas, is where the most urgent research is needed. Probabilistic methodologies can be implemented to provide precisely the necessary probabilistic information that is necessary for developing priorities on R&D funding strategies. Here again it would appear that the information about uncertainty is more important than the expected values.

3. AEGIS SIMULATION MODEL

This simulator should be viewed as a framework for assembling and manipulating information about the economics, emissions, ambient concentrations, and potential health impacts of different types and configurations of electric power generating facilities. The framework is probabilistic, and thus results in several measures of the range of various consequences, in other words, a graphic display of the quality of the various predictons.

Ths Aegis model, apart from the other areas of research on this project, is a relatively small scale effort, receiving about 800 man-hours of funding. Much of this time has been spent on the encoding of the simulator, with some student and researcher time focused on the collection of data. This section ofthe summary report is intended to give a summary of the structure and structural issues related to the model. Additional detail and data within the model's framework are frequently changed and thus are left described in the annotated listing of the computer code. The latest version is available upon request, and although this version will change, it is hoped that the structural issues related in this section will remain valid through the future series of revised model versions.

3.1 Summary of Capabilities

This document contains discussions about a computerized tool for predicting the economics, resource uses, emissions, ambient concentration, and health impact levels from combinations of:

1) fuel types and sources,

2) pretreatment equipment

3) generation equipment

4) abatement equipment

5) site types for different dispersive potentials,

6) site types for different population densities, and

7) available health effects models.

The framework of this mechanism has been the principal focus of this portion of the project, although a number of existing government and industry sources have been searched for data relevant to this mechanism. Some of the structural issues addressed have included:

1) types of components that should explicitly be incorporated,

2) mechanisms for modular addition or updating of data,

3) generic pieces of information that could easily be used for testing and simple exercises,

4) specific air pollutants that should be collected within the simulator,

5) the treatment and display of probabilistic information and models, and finally

6) means for evaluating the validity of complex computerized models.

The majority of this part of the project was spent on the structural issues previously listed. The data base, thus, is the weakest portion of this project, and any uses of the simulator should be carefully augmented with a study of the adequacy of the underlying data. Fortunately, it is not difficult to update the data base in any of the sections of the simulator.

First, it is important to understand the basic structure of the model. All of the quantities collected or manipulated within the model correspond to actual physical flows. Figure 3-1 shows some of these flows that take place in the standard use of the model. There are two principal advantages

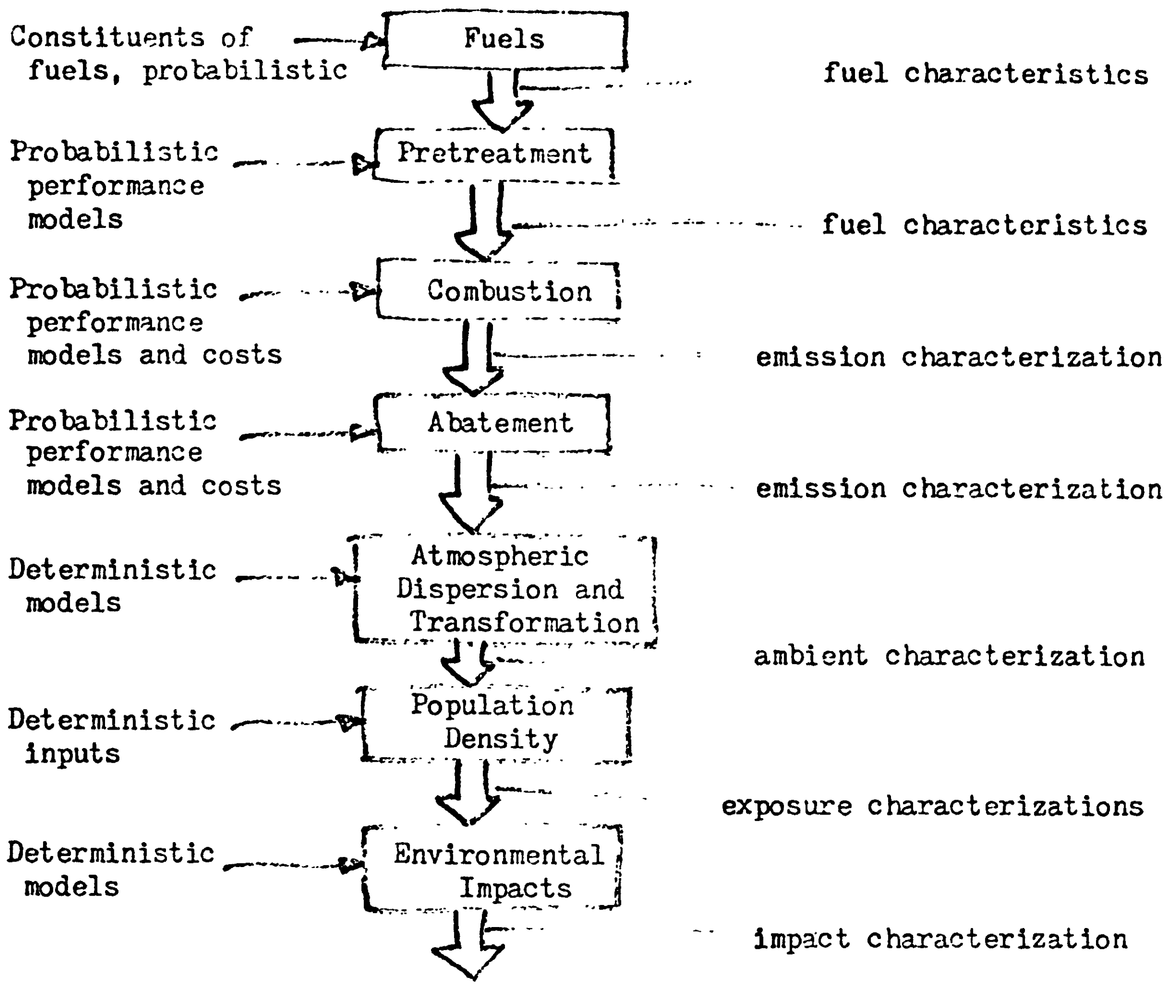


Figure 3-1 General information flow of the AEGIS model

of such a "physically significant" framework, namely:

1) all of the data requirements correspond to real measurements that can be made, and
2) the structure is simple enough to allow for a quantification of the profile of the uncertainty associated with any of the flows or eventual outputs.

It is not immediately obvious what types of internal variables must be collected to ensure the appropriate performances of the various options, and this has been an area of considerable effort in the setup of the framework of the current model version.

Although there is considerable unevenness in the qualities of the different data, Table 3-1 to 3-5 are a listing of the modules which are in place in the current version of the simulator.

The question of accuracy, or validity, is paramount in the minds of informed users of any large computerized models. An extensive undertaking into the area of model validity has been conducted as part of this project. The conclusion was that the ideal situation would be to quantitatively display the validity of all outputs as a normal course of the report generating phase. This has been accomplished in this project, and may be a unique and important aspect of this project.

In closing this subsection it is important to list briefly some of the obvious limitations in the use of this model as well as some of the potential application areas:

Model Limitations

1. No background pollutant concentrations (nonlinear health models are not accurately usable)
2. Not a design tool - designs are fixed at attractive options
3. Not a financial model
4. Air quality projections are simplistic, as in screening models
5. Correlations not immediately evident - e.g. capital costs versus emissions

Table 3-1 Fuel Module Options

D0101	Free Fuel and Geothermal
D0102	National Average Bituminous Coal
D0103	Midwestern Penn Bituminous Coal
D0104	Pittsburgh Seam Bituminous Coal
D0105	West Virginia Bituminous Coal
D0106	Eastern Ohio Bituminous Coal
D0107	Eastern Kentucky Bituminous Coal
D0108	Western Kentucky Bituminous Coal
D0109	Illinois No. 6 Bituminous Coal
D0110	Southern West Indiana Bituminous Coal
D0111	Mississippi-Oklahoma-Texas Lignite
D0112	Western Colorado Coal
D0113	Wyoming Subbituminous Coal
D0114	Western Dakotas Lignite
D0115	East Central Montana Coal
D0116	Narragansett Anthracite Coal
D0117	Nuclear Fuels
D0118	Domestic Light Turbine Oil
D0119	Average Domestic Residual Oil
D0120	Venezualan Residual Fuel Oil
D0121	Shale Oil
D0122	Natural Gas
D0123	Solid Waste Municipal
D0124	Solid Waste Forest Residual
D0125	Solid Waste Agricultural Residual
D0126	Biomass Plantation Fuel
D0127	Vacant
D0128	Vacant
D0129	Vacant

Table 3-2 Combustor/Generator Module Options

D0301	Coal Direct Conventional Combustion
D0302	Fluidized Bed Atmospheric Standard
D0303	Fluidized Bed Atmospheric Low Pollution
D0304	Fluidized Bed Pressurized Standard
D0305	Fluidized Bed Pressurized Low Pollution
D0306	MHD Open Cycle
D0307	MHD Closed Cycle
D0308	Coal-Oil Slurry Combustion
D0309	Combined Cycle Coal No. 1
D0310	Combined Cycle Coal No. 2
D0311	Combined Cycle Coal & Low BTU
D0312	Combined Cycle Coal Oil
D0313	Combined Pyrolysis Coal
D0314	Fuel Cell Phosphoric Acid
D0315	Fuel Cell Molten Carbonate
D0316	Oil Direct Fired Combustion
D0317	Gas Turbine Conventional
D0318	Gas Direct Fired Boiler
D0319	Light Water Reactor Pressurized
D0320	Light Water Reactor Boiling
D0321	High Temperature Gas Reactor
D0322	Liquid Metal Fast Breeder Reactor
D0323	D T Tokamak Fusion Reactor
D0324	Waste-Coal Mixture Direct Combustion
D0325	Waste or Residue Direct Combustion
D0326	Hydroelectric
D0327	Low Head Hydroelectric
D0328	Wind Two Blade Device
D0329	Wind Verticle Axis
D0330	Solar Thermal Central Open
D0331	Solar Thermal Closed Hybrid
D0332	Solar Photovoltaic Silicon
D0333	Solar Photovoltaic Cadmium
D0334	Geothermal Hot Water
D0335	Geothermal Two Stage Flash
D0336	Geothermal Multi-Stage Flash
D0337	Geothermal Steam Flash Hybrid
D0338	Ocean Thermal Submerged
D0339	Ocean Thermal Ship
D0340	Ocean Thermal Spar
D0341	Wave Power
D0342	Tidal Power
D0343	Vacant
D0344	Vacant
D0345	Vacant

Table 3-3 Miscellaneous Modules

D02 PRETREATMENT MODULE

D0201 NONE
D0202 PHYS COAL CLEAN 3 BENEFI
D0203 PHYS COAL CLEAN 4 BENEFI
D0204 SOLVENT REFINED COAL
D0205 COAL LIQUEFACTION FUEL
D0206 OIL DESULFURIZATION
D0207 VACANT

D04 ADDITIVE MODULE

D0401 NONE
D0402 RAW LIMESTONE NO 1359

D05 PARTICULATE ABATEMENT MODULE

D0501 NONE
D0502 BAGHOUSE FILTER
D0503 96% ELECTROSTATIC PRECIP
D0504 99% ELECTROSTATIC PRECIP
D0505 HIGH INTENSITY IONIZER

D06 OTHER ABATEMENT MODULE

D0601 NONE
D0602 SCRUBBER LIMEST THROWAWAY
D0603 SCRUBBER LIME THROWAWAY
D0604 SCRUBBER NC O REGENERABLE
D0605 NOX REMOVAL SCRUBBER
D0606 NH3 CATALYTIC NOX REMOV

D07 ATMOSPHERIC MODULE

D0701 STANDARD DILUTION SCALE
D0702 LOW 1 DILUTION SCALE
D0703 LOW 2 DILUTION SCALE
D0704 LOW 3 DILUTION SCALE
D0705 LOW 4 DILUTION SCALE
D0706 LOW 5 DILUTION SCALE
D0707 HIGH 1 DILUTION SCALE
D0708 HIGH 2 DILUTION SCALE
D0709 HIGH 3 DILUTION SCALE
D0710 HIGH 4 DILUTION SCALE
D0711 HIGH 5 DILUTION SCALE
D0712 VACANT

D08 AEROCHEMICAL MODULE

D0801	NO SULFATION
D0802	SULFATION MAS+BROOKHAVEN
D0803	NO PHOTOCHEMICAL
D0804	PHOTOCHEMICAL SMOG MODEL
D0805	NO ORGANIC
D0806	ORGANIC AEROCHEMICAL

D09 DEMOGRAPHIC MODULE

D0901	AVE OF ALL DENSITY PATT
D0902	INDIAN POINT IN 1980 EST
D0903	ZION IN 1970 ACTUAL
D0904	CALVERT CLIFFS IN 1970
D0905	TROJAN IN 1980 ESTIMATE
D0906	FARLEY IN 1972 ACTUAL
D0907	HANFORD IN 1980 ESTIMATE
D0908	**VACANT**

Table 3-4 Chemical Pollutant Health Effects Models

D1001	None
D1002	Average of All Chemical Health Models
D1003	LAMM - Linear Additive Mortality Model
D1004	Amdur Synergistic Toxicology Model
D1005	Bozzo Linear 1977
D1006	Buechley Model
D1007	Carnow Meier 1973
D1008	Chapman Shy 1973
D1009	Chess 1976 Model
D1010	Crocker EPA Linear Model
D1011	Ferris Model
D1012	Finklea 1975 Model
D1013	Glasser Greenburg Model
D1014	Goldstein Block 1974 Model
D1015	Gotchy Linear Model
D1016	Gregor 1976 Model
D1017	Hamilton Brookhaven Model 1978
D1018	Hamilton Manne 1967
D1019	Hexter Goldstein 1971 Model
D1020	Hickey Boyce Trace Element Model
D1021	Hodgson Model
D1022	International Inst Applied Systems Analysis Model
D1023	Kitagawa Hauser Linear 1973
D1024	Koshal Log Linear 1973
D1025	Lambert 1970 Model
D1026	Lammers Schilling Model
D1027	Larsen 1970 Synergistic Model
D1028	Lave Freeburg 1973 Model
D1029	Lave Seskin 1969 Model
D1030	Lave Seskin 1972 Model
D1031	Lawther Model
D1032	Lee Fraument 1969 Model
D1033	Lindeberg Model
D1034	Lipfert Linear 1978 Model
D1035	Liu Yu Nonlinear 1979 Model
D1036	Martin Bradley Model
D1037	McDonald Schwing 1973
D1038	Mendelsohn Orcutt 1978
D1039	Meyers Cederwall Model
D1040	Morgan Probabilistic Model
D1041	Morris Noval Model
D1042	North Merkhofer NAS Model
D1043	Riggan 1972 Model
D1044	Schwing McDonald 1976
D1045	Smith Linear 1976 Model
D1046	Thilly Cancer Toxic Model
D1047	Thomas Linear 1973 Model
D1048	Winkelstein Linear 1967
D1049	Winkelstein Nonlinear 1967
D1050	Vacant
D1051	Vacant
D1052	Vacant

Table 3-5 Other Impact Modules

D11	RADIATION HEALTH MODULE
D1101	NONE
D1102	AVER OF ALL RAD DOSE MOD
D1103	BEIR NAS 1972 DOSE MODEL
D1104	CRSRC RFC 1976 DOSE MOD
D1105	NCRP 1976 DOSE MODEL
D1106	REPSC REVISE 1977 MODEL
D1107	UNSCEAR 1976 DOSE MODEL
D1108	WASH-1400 1975 DOSE MOD

D12	OTHER IMPACT MODULE
D1201	NONE
D1202	AVER OF ALL COST MODELS
D1203	HAMILTON-BLOOFH COST MOD
D1204	FREESE COST MODEL
D1205	LAVE SESKIN 1969 COSTS
D1206	LAVE SESKIN 1972 COSTS
D1207	NAT ACADEMIES COST MODEL
D1208	API-ONTAR AIR POLL INDEX
D1209	AQI-AIR QUALITY INDEX
D1210	CI-GREENS COMBINED INDEX
D1211	CPI-COMPIST PROP INDEX
D1212	EVI-EXTREME VALUE INDEX
D1213	IAPPEIS SCHILLING INDEX
D1214	MAQI-MITRE AIR QUAL IND
D1215	ORAQI-OAK RID AIR Q IND
D1216	PINDEX-IHP LIN ADD INDEX

6. Dispersion, population, and health models are deterministic (mostly)
7. No particulate size distributions
8. Pre-specified storage capabilities

Potential Applications

1. For use in choosing among various fuels, combustors, abatement, and site options
2. Defining uncertainties and potential risks in situations
3. R&D planning
4. Public awareness information
5. Pollution control cost-benefit analysis (e.g. for PSD BACT arguments)
6. Ambient standards cost-benefit analysis
7. Cross-validation of health models

For a discussion of the development of the AEGIS structure and its limitations the reader should refer to (Gruhl, Nov. 1978). For a detailed understanding of the model the code has been annotated to answer a number of concerns. One detail that is not described in the code is the manner in which probabilities are concatenated.

The probabilistic treatments in the current version of AEGIS are somewhat of an approximation. Before discussing how it is now accomplished it is instructive to discuss how it should be done ideally. Beginning with the deterministic notation:

$$\underline{y} = \underline{f}(\underline{x})$$

where

$\underline{y}$ = the vector of model outputs,

$\underline{x}$ = the vector of model inputs, and

$\underline{f}$ = the functional combinations of inputs that create the outputs.

Now instead of constant deterministic values, suppose the inputs are specified as functions representing the probabilistic distribution of the values of the inputs, say $\underline{x}_p$. Likewise the outputs would then be functions $\underline{y}_p$ generated by convolutions and other combinations, $\underline{F}$, of the inputs. Thus, the ultimately precise probabilistic formulation would be

$$\underline{y}_p = \underline{F}(\underline{x}_p)$$

The problem with this ideal method is that the functions cannot be precisely stored in a computer, thus a discretized representation of the input and output are the best that can be used $\underline{x}_n$, $\underline{y}_n$. In the current version of the simulator there are five discrete points that represent the probablistic distribution, the points at which the probability of being less than that value is 0%, 16%, 50%, 84%, and 100%. Now the problem with these discrete values is that neighter $\underline{f}$ nor $\underline{F}$ is the appropriate transforming function. There are two possible approaches to the development of the appropriate discrete transform. The first requires the fitting of functional relationships, from a set of generalized probability functions, to the discrete points. This somewhat regenerates $\underline{x}_p$ from $\underline{x}_n$ and is termed $\hat{\underline{x}}_n$. Now, assuming $\hat{\underline{x}}_n$ is very close to $\underline{x}_p$

$$\underline{y}_p \approx \underline{F}(\hat{\underline{x}}_n).$$

This $\underline{y}_p$ can be discretized to develop $\hat{\underline{y}}_n$. For a given set of generalized probability functions it should be possible to develop a general formula, $\underline{G}$, for obtaining the $\hat{\underline{y}}_n$:

$$\hat{\underline{y}}_n = \underline{G}(\hat{\underline{x}}_n).$$

The details of this have not been worked out.

The second approach is the more approximate approach and involves worst case analysis. Suppose $\underline{x}_m$ is such that m is 2, that is the minimum and maximum values of $\underline{x}_p$. It is computationally quite easy, for any $\underline{f}$, to determine the $\underline{y}_m$, that is, the minimum and maximum values, of $\underline{y}_p$, by simple tests using $\underline{f}$ over the range between the minimum and maximum, $\underline{x}_m$. Call this transform $\underline{g}$:

$$\underline{y}_m = \underline{g}(\underline{x}_m).$$

What would ahppen if we were to operate $\underline{g}$ on $\underline{x}_n$, $n = 5$; in fact does

$$\underline{y}_n \approx \underline{g}(\underline{x}_n),$$

that is

$$\underline{y}_{1,5} \approx \underline{g}(\underline{x}_{1,5}),$$

$$\underline{y}_{2,4} \approx \underline{g}(\underline{x}_{2,4}),$$

$$\underline{y}_3 \approx \underline{g}(\underline{x}_3).$$

It can be thoughtout that $\underline{y}_1$ and $\underline{y}_5$ will be perfectly accurate. The middle point $\underline{y}_3$ is not precisely the same as $\underline{g}(\underline{x}_3)$, but it does happen that $\underline{g}(\underline{x}_3)$, while not the median, is the deterministic case, which has some value. The deviation points, $\underline{y}_{2,4}$, are also not precise, but they are very close. The advantages of this second approach are the ease of its implementation and the speed of its computation.

3.2 Input/Output Procedures

The input and output procedures for this simulator are quite straightforward. For the sake of example, the procedures for the use of the interactive form of the simulator are presented. A flowchart of the procedure is presented in Figure 3-3 showing the potential paths through the various subroutines in the simulator.

Table 3-6 displays the input information required to operate the model. This input informations is listed again in the beginning of the output report so as to act as a formal record of the conditions for the simulation run. Table 3-7 presents the output from a sample simulation, displaying the range of uncertainty associated with each of the 109 performance measures. Minus numbers, such as -1., or letters, such as NA, are indications that these are performance values that are not predicted by the particular modules chosen by the user.

Assimilating the important information from these long lists of performance measures could be a formidable task. It could be even more difficult to make a comparison of several alternative sets of performance measures. Some thought has been given as to how such comparisons and evaluations could be made. Although it has not been computerized, Figure 3-4 represents a procedure that could be operated manually or possibly even examined for ideas about comparative techniques.

3.3 Status of AEGIS Modules

It was the original intent for the structure of this simulator to carry with it the documentation for every number and every function in an on-line retrievable file. Table 3-3 shows the retrieval index; and Table 3-9 shows a sample of the way in which this documentation was initially intended to be set up. There were two major problems with this idea. First, the storage requirements for this material grew to the point where it was resulting in an unjustifiable expense. Second, all of the users initially interested in the simulator were only interested in the batch mode version. For these reasons the documentation is not now carried on-line.

It is appropriate here to discuss some of the general characteristics of the various modules. As shown in Figure 3-1, the first module encountered is the fuels module. For each different fuel type there is information about its cost, heat content, mineral and moisture contents,

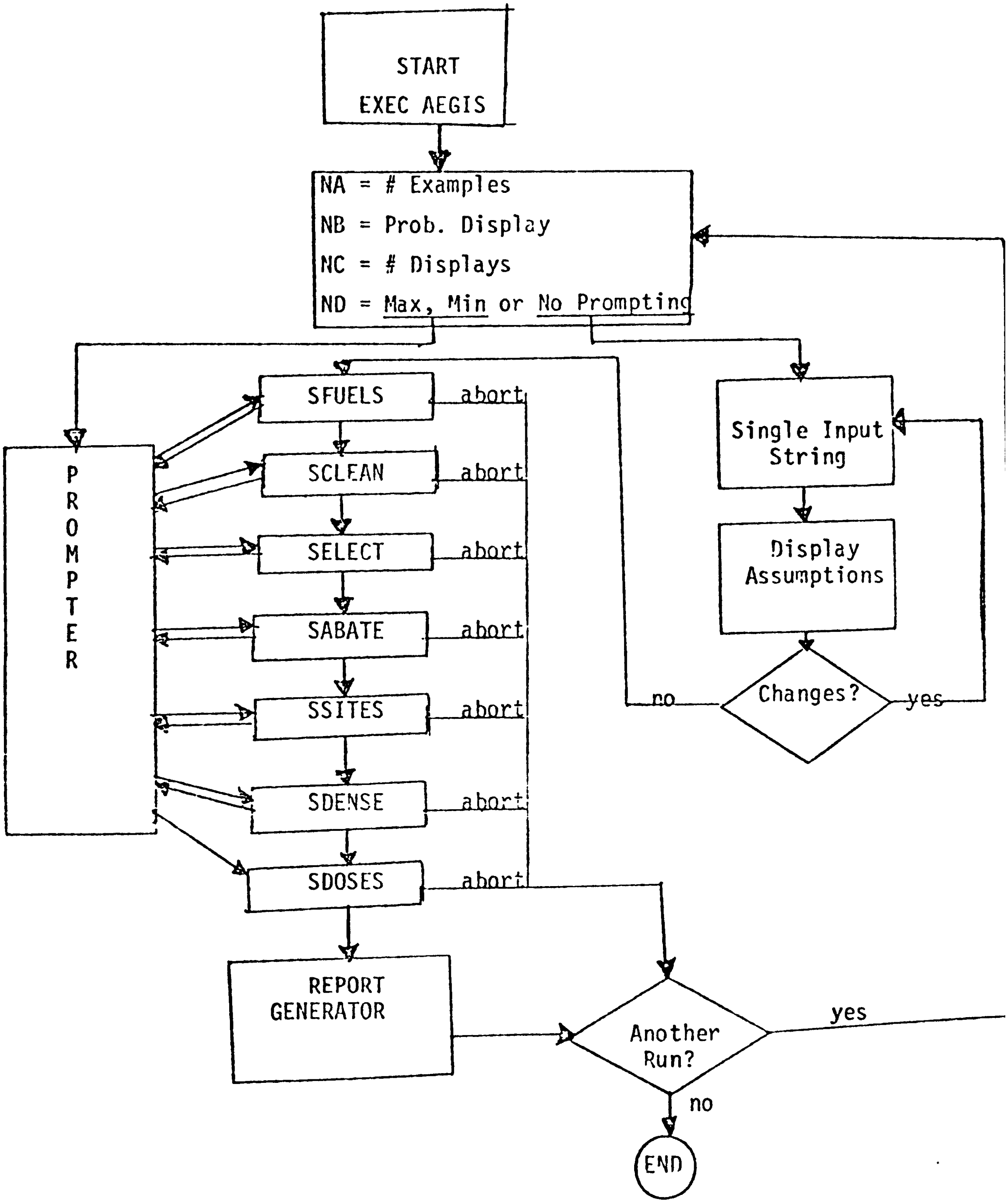


Figure 3-3 Flowchart of Procedures for the Use of the Interactive Version of the Simulator

Table 3-6 Input Requirements

1. Facility Size (MWe)
2. Year Completed
3. Fuel Type
4. Precleaning Type
5. Generation/Combustion Type
6. Designed Capacity Factor (%)
7. Storage Capacity (MWhr)
8. Sorbent Type
9. Particulate Abatement Type
10. Scrubber Type
11. Stack Height (m)
12. Stack Diameter (m)
13. Meteorological Site Type or new Climatological Profile (16x8x6 Star frequency array)
14. Aerochemical Sulfation Type
15. Aerochamical Smog Type
16. Evaluation Radii Distances (default or 10 new radii in km)
17. Population Density Type or new Density Profile (by angle and radii 16x10)
18. Population Scaling Parameter
19. Reorientation of meteorological and Population Patterns (add 0 through 15 sector displacements)
20. Chemical Health Impact Model tupe
21. Radiation Health Impact Model Type
22. Pollution Index Model Type

Table 3-7 Sample Output from AEGIS

CUMULATIVE PROB MEASURES / PROB VALUE < THIS VALUE	MINIMUM .0000	1 DEV LO .1587	MEDIAN .5000	1 DEV HI .8413	MAXIMUM 1.0000
ECONOMIC FACTORS					
INVEST COST<MIL $>	1219.8	1364.2	1529.5	2095.7	2736.0
NORMALIZED INVEST<$1000/MWE>	642.00	718.00	805.00	1103.0	1440.0
OPERATING COSTS:					
FIXED OPER COST<$/MWE/YR>	85848.	.13920E+06	.15637E+06	.21339E+06	.23118E+06
VARIABLE OPER COST<$/MWH>	7.7000	8.0000	10.100	12.000	15.000
OP&MAIN<$/MWH>	1.6000	1.7000	2.8000	3.2000	4.0000
FUEL<$/MWH>	6.1000	6.3000	7.3000	8.8000	11.000
COST OF ELECT<MILS/KWH>	27.100	36.000	42.000	48.500	55.500
CAP COST<MILS/KWH>	14.000	22.700	25.500	34.800	37.700
OP COST<MILS/KWH>	1.6000	1.7000	2.8000	3.2000	4.0000
FUEL COST<MILS/KWH>	6.1000	6.3000	7.3000	8.8000	11.000
PERFORMANCE FACTORS					
OPER CAP FAC<%>	55.000	63.000	68.000	70.000	75.000
ENERGY EFF ONSITE<%>	45.600	47.000	48.300	48.700	49.200
APPLICABILITY					
COMMERC YR<2000MWE ONLINE>	1995.0	1996.0	1999.0	2003.0	2021.0
INSTALLED CAP<MWE>	83.000	83.000	83.000	83.000	83.000
LARGEST FACILITY<MWE>	70.000	70.000	70.000	70.000	70.000
RESOURCE REQUIREMENTS					
LAND USE ONSITE<ACRES>	70.490	96.900	370.50	659.30	1187.5
LAND DISTURB FUEL<ACRES/YR>	65.845	98.767	115.23	131.69	148.15
LAND DISPOSE WASTE<ACRES/YR>	59.850	86.450	119.70	151.62	196.84
WATER CONSUMP<MIL GAL/YR>	2394.0	2926.0	4123.0	5985.0	7315.0
ENVIRONMENTAL CONSEQUENCES					
AIR EMIS ONSITE<GM/MIN>:					
SOX	118.42	1328.2	40582.	.11234E+06	.36279E+06
SULFATES	9.4734	92.973	2840.7	7863.5	25285.
SULF ACID AEROS	1.4802	13.282	481.91	1310.6	4232.5
NOX	5700.0	14250.	17100.	29450.	64600.
NO	5700.0	14250.	17100.	29450.	64600.

Table 3-7 (continued display of output from AEGIS)

O3, OXID	.64600E-03	.20900E-02	.64600E-02	.20330E-01	.64600E-01
PART TOTAL	9690.0	47500.	77900.	98800.	.11590E+06
PART RESPIR	7030.0	32300.	55100.	68400.	81700.
CO	15960.	53200.	.15960E+06	.53200E+06	.15960E+07
CO2	.38000E+07	.47500E+07	.57000E+07	.76000E+07	.11400E+08
HC TOTAL	30.400	98.800	304.00	988.00	3040.0
INERT HC	24.320	79.800	243.20	798.00	2432.0
REACTIVE HC	3.0400	9.8800	30.400	98.800	304.00
OXYG HC	.30400	.98800	3.0400	9.8800	30.400
POLY ORG MAT	2.6600	8.9300	26.600	89.300	273.60
TRACE ELEM:					
ARSEN	.40006E-01	3.9494	22.435	130.49	297.64
BERYL	.16002E-01	.82172	4.8951	12.249	24.003
CAD	.80011E-02	.38406	6.6538	116.66	338.05
CHROM	.32005	8.8277	55.008	141.21	432.06
COB	.80011E-01	2.5876	30.628	90.222	275.24
LEAD	.32005	8.2828	55.656	322.55	697.70
MANG	.48007	12.582	197.63	601.86	1448.2
MERC	.16002E-02	.24003E-01	.80011E-01	.25604	1.2802
NICK	.24003	11.861	84.292	221.94	633.69
SELEN	.36005E-01	.47047	2.4964	6.3609	18.483
TIN	.80011E-01	2.3395	19.163	113.49	403.98
VANAD	.88013	19.856	91.601	211.20	436.86
ZINC	.48007	31.204	784.31	8017.2	30820.
RADIOACT TO AIR<CUR/YR>	.35375E-03	.30310E-01	.11002	.22792	.53063
WATER EMIS ONSITE<TONS/YR>	.45680E+06	.52100E+06	.57614E+06	.63952E+06	.73252E+06
INORGANIC<TONS/YR>	.41153E+06	.46914E+06	.51853E+06	.57614E+06	.65845E+06
ORGANIC<TONS/YR>	45268.	51853.	57614.	63375.	73252.
THERMAL<10*12 BTU/YR>	26.338	27.984	28.807	29.630	30.453
RADIOACT TO WAT<CUR/YR>	.0	.0	.0	.0	.0
SOLID WASTES<TONS/YR>	.37038E+06	.41976E+06	.46091E+06	.51030E+06	.58437E+06
RADIOACT SOLIDS<CUR/YR>	.0	.0	.0	.0	.0
ATMOS DILU FAC<UG/M3/G/MIN>					
GASEOUS:					
1 HOUR	.83301E-06	.14072E-05	.33154E-05	.66555E-05	.11353E-04
3 HOUR	.15048E-05	.25421E-05	.59892E-05	.12023E-04	.20509E-04
8 HOUR	.19885E-05	.33592E-05	.79143E-05	.15887E-04	.27101E-04
24 HOUR	.25796E-05	.43578E-05	.10267E-04	.20611E-04	.35158E-04
3 DAY	.32783E-05	.55381E-05	.13048E-04	.26193E-04	.44680E-04
1 MON	.44069E-05	.74446E-05	.17540E-04	.35210E-04	.60062E-04
ANNUAL	.53742E-05	.90788E-05	.21390E-04	.42939E-04	.73246E-04
PARTICULATES:					
1 HOUR	.57056E-06	.74611E-06	.19311E-05	.34233E-05	.51789E-05
3 HOUR	.10307E-05	.13478E-05	.34885E-05	.61841E-05	.93554E-05
8 HOUR	.13620E-05	.17810E-05	.46098E-05	.81719E-05	.12363E-04
24 HOUR	.17669E-05	.23105E-05	.59802E-05	.10601E-04	.16038E-04
3 DAY	.22454E-05	.29363E-05	.75999E-05	.13473E-04	.20381E-04
1 MON	.30184E-05	.39472E-05	.10216E-04	.18111E-04	.27398E-04
ANNUAL	.36810E-05	.48136E-05	.12459E-04	.22086E-04	.33412E-04

OCCUP HEALTH:					
MORT ONSITE<PER YR>	.63776E-01	.82703E-01	.10768	.13757	.17970
MORB ONSITE<PER YR>	.63776	.87665	1.8521	3.3016	4.4926
DAYS LOST ONSITE</YR>	239.16	364.72	792.55	1283.9	1797.0
MORT OFFSITE<PER YR>	.79720E-01	.41351	.86146	1.3757	2.1964
MORB OFFSITE<PER YR>	2.1524	4.7140	54.617	87.583	100.83
DAYS LOST OFFSITE</YR>	53.731	154.65	294.62	3466.7	9584.2
PUBLIC HEALTH<ROUTINE>:					
MORTALITIES<PER YR>	.94463E-01	1.0952	6.3197	18.926	56.097
CANCER<TOTAL>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
CARDIOVAS	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
BRONCHOPULM	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
CNS	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MUTATIONS<TOTAL>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MORBIDITIES<PER YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
RESPIR	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
ASTHMA	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
PNEUM	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
CHRONIC	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
CHILDREN	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
THYROID	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
CARDIOVAS	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MANDAYS LOST<PER YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
PUBLIC HEALTH<OFFSITE>:					
MORTALITIES<PER YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
CANCER<TOTAL>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MUTATIONS<TOTAL>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MORBIDITIES<PER YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MANDAYS LOST<PER YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
PUBLIC HEALTH<CATAST>:					
PROB OF OCCUR<PER YR>	.79720E-07	.39697E-06	.68917E-06	.11739E-05	.15974E-05
MORTALITIES<PER YR>	.63776	1.2405	1.5506	1.9259	2.7954
CANCER<TOTAL>	.39860E-05	.25638E-04	.56857E-04	.35767E-03	.86856E-03
BRONCHOPULM	.11958E-04	.49622E-04	.21537E-03	.50441E-03	.11980E-02
CARDIOVAS	.79720E-04	.37216E-03	.86146E-03	.20176E-02	.89851E-02
MUTATIONS<TOTAL>	-1.0000	-1.0000	-1.0000	-1.0000	[illegible]
MORBIDITIES<PER YR>	6.3776	17.368	24.121	32.099	40.932
THYROID	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MANDAYS LOST<PER YR>	637.76	1736.8	2412.1	3209.9	4093.2
INDEXES AND COSTS:					
PUBLIC HEALTH COSTS<$/YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
BIOTA COSTS<$/YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MAT DAMAGE COSTS<$/YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
AESTH COSTS<$/YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
SUBJECTIVE INDEXES	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000

```
FOR ANOTHER RUN TYPE: DO    OR: NOT
not
END
```

Table 3-7 Completion of display; -1.0 values indicate information not predicted by modules chosen.

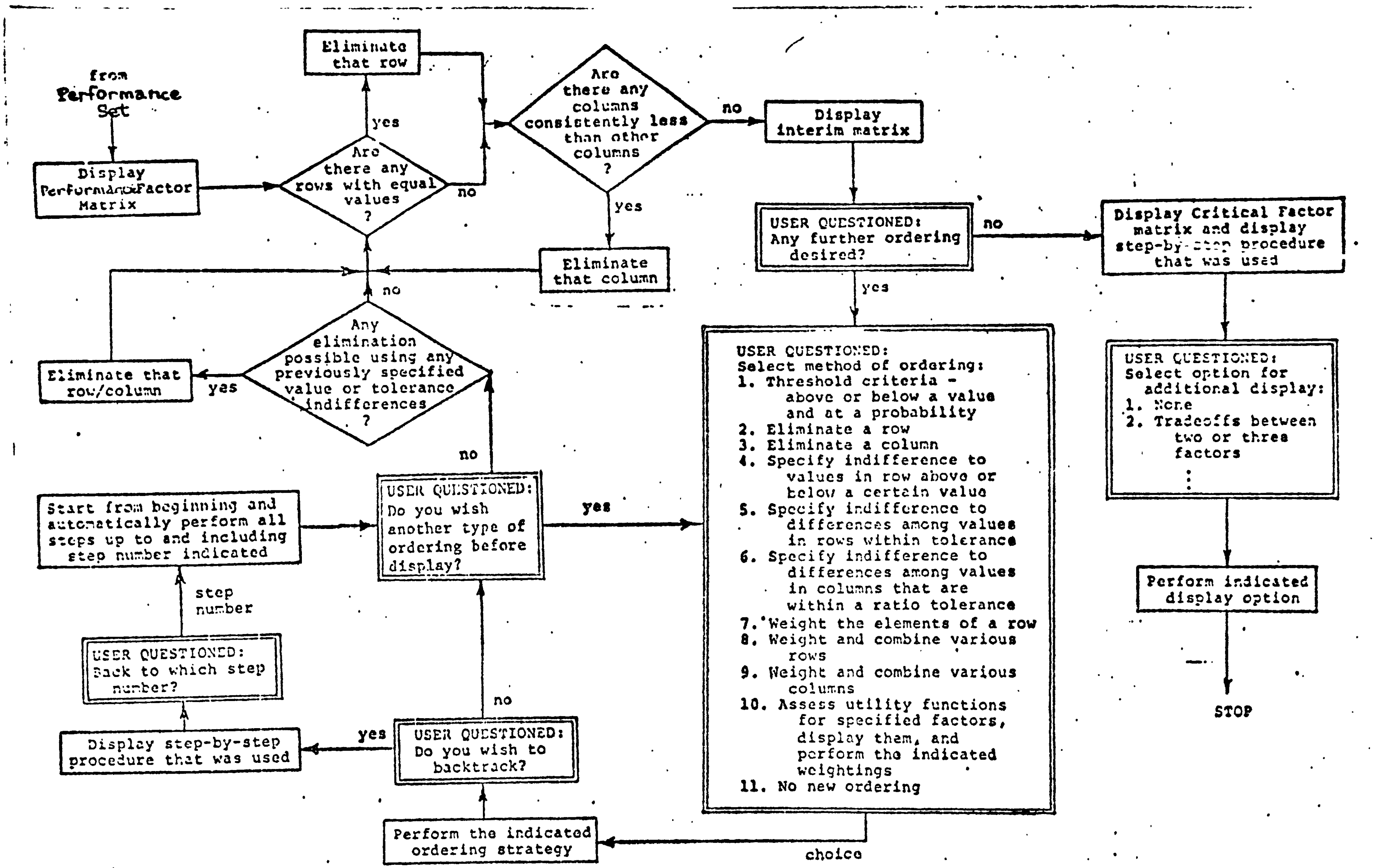


Figure 3-4 Flowchart showing the decisions, actions, and questioning that could be performed to develop priorities between lists of performance measures.

elemental constituencies, and occupational hazards per million BTU. The costs of the fuels are collected on a per quantity basis as delivered to the center of the New England area and prepared for power plant use. To make these costs generally applicable would require changing the costs to mine-mouth costs, querying the user about the specific geographic location of the facility, and creating a lookup table of transportation modes and costs between the supply and demand regions. Such costs are readily available as this type of exercise is carried out in many national energy system models, for example the ICF Coal and Electric Utilities Model. All costs are in terms of 1978 dollars, and in the current version there are no real escalation rates for facilities planned for some time far in the future.

Precleaning is an option. If a type of coal or oil precleaning is selected, the fuel data is massaged to account for losses, costs, removal efficiencies, additional occupational hazards, and so on. Precleaning adds only to the cost of the fuel, not to the investment cost of the generating facility. In the case of dedicated precleaning facilities it may be important to recode this portion to carry forward the investment costs.

The generation options are modeled with their principal sophistication in the emissions portions. Economics, availabilities, resource consumptions, and other factors are carried along, but without some of the flexibility one might like to have. Table 3-10 for example, shows some additional sophistication that might be important to add to the economic capabilities of the simulator. In addition, storage capabilities are not included in the simulator, except some inflexible proportions that are tied to some of the alternative sources, such as solar and wind generators. The intent of the simulator was to be a collection of the front runners, as far

Table 3-8 Outline of documentation format and code

```
 AEGIS DOCUMENTATION IDENTIFICATION CODE

AEGIS - ALTERNATIVE ELECTRIC GENERATION IMPACT SIMULATOR, VERSION M005D012
FOR FURTHER INFORMATION CONTACT: J. GRUHL, E38-408, 77 MASS. AVE., CAMBRIDGE MA
                                    (617)253-8025 OR MESSAGE AT -3404
D = DOCUMENTATION TEXT IDENTIFIER
|NN = MODULE NUMBER       01=FUELS
|||                       02=PRETREATMENT
|||                       03=COMBUSTION
|||                       04=ADDITIVE
|||                       05=PARTICULATE ABATEMENT
|||                       06=OTHER ABATEMENT
|||                       07=ATMOSPHERIC CHARACTERISTICS AND DISPERSION MODEL
|||                       08=AEROCHEMICAL MODEL
|||                       09=DEMOGRAPHIC CHARACTERISTICS
|||                       10=CHEMICAL HEALTH IMPACTS
|||                       11=RADIATION HEALTH IMPACTS
|||                       12=OTHER IMPACT MEASURES
|||NN = SPECIFIC MODEL (WITHIN MODULE)
|||||NN = DESCRIPTIVE INFORMATION (FOR SPECIFIC MODEL)
|||||||NN = LINE NUMBERS (FOR SAME DESCRIPTIVE INFORMATION)
|||||||||           LINES 01=CONCENSUS PROBABILISTIC BREAKDOWN, FIVE NUMBERS
|||||||||                       MINIMUM, .00 CUMULATIVE PROBABILITY
|||||||||                       ONE DEV LOW, .16 CUMULATIVE PROBABILITY
|||||||||                       MEDIAN, .50 CUMULATIVE PROBABILITY
|||||||||                       ONE DEV HIGH, .84 CUMULATIVE PROBABILITY
|||||||||                       MAXIMUM, 1.00 CUMULATIVE PROBABILITY
|||||||||                 02 TO 09=CORRELATED CONDITIONALS
|||||||||                 10 TO 99=SPECIFIC SOURCES AND NUMBERS
D11223344
   IS EXAMPLE DOCUMENTATION LINE IDENTIFIER FOR INFORMATION ABOUT MODULE 11,
       MODEL 22, ROW OF DESCRIPTIVE INFORMATION 33, LINE 44
```

Table 3-9 Documentation of LAMM Health Impact Model

```
D10030000     VERSION D013
D10030001 DESCRIPTION  LINEAR ADDITIVE MORTALITY MODEL - LAMM.
D10030002  CRUDE, LINEAR MODEL BASED UPON CONCENSUS STANDARDS, IT ONLY
D10030003  PREDICTS ANNUAL INCREASES IN MORTALITY RATES, SOURCE IS
D10030004  (GRUHL,ET AL,NOV1976,P106), ACCURACY DEPENDS ON AMONG OTHER THINGS
D10030005  SMALLNESS OF REGIONS CONSIDERED
D10030010   TOTAL ADDITIONAL ANNUAL MORTALITIES PER 10*6 PERSONS IN SOME
D10030011   REGION NEAR POINT SOURCE = SUMMATION (REGIONAL MAXIMUM UG/M3 24HR
D10030012   AVERAGE CONCENTRATIONS OF NOX/455 + SOX/365 + CO/710000 + PART/260
D10030013   + ARSEN/.15 + BERYL/.01 + MERC/.10 + NICK/.03 +
D10030014   + RADIUMS(CURIES/YR)/.02 )
```

as designs were concerned, in each of the major generator types. For fluid bed combustors, where there are several "front runners" it was necessary to create several different choices. This, of course, would be possible for some of the other combustion types, or it would be possible to pull out some key design parameters as options. The latter course would require only a little more effort to implement in the current version of the simulator, but would require extensive information about the system's overall performance as a function of the variable parameter.

Additional sophistications in the generation module could include explicit handling of costs during construction, different materials use problems and variations in costs as a function of greater or lesser amounts of ash, etc., or a more explicit and accurate handling of water and solid pollutants.

The abatement module, in the current version, is not very sophisticated. The procedure is much the same as the precleaning module except that emissions constituencies are treated rather than fuel constituencies. One of the major improvements that is needed in this module is a modeling and treatment of particulate size distributions. There are very different expectations and costs of precipitators based on the size distributions of the particulates.

There was an initial effort to make the atmospheric dispersion and the population density information responsive to specific situations. Figure 3-5 shows the general capabilities included in the dispersion model, and Figure 3-6 is a flowchart of that POLCON model. It quickly became apparent that the amount of input information would create a tremendous burden for the user. The principal reason for this burden is that there

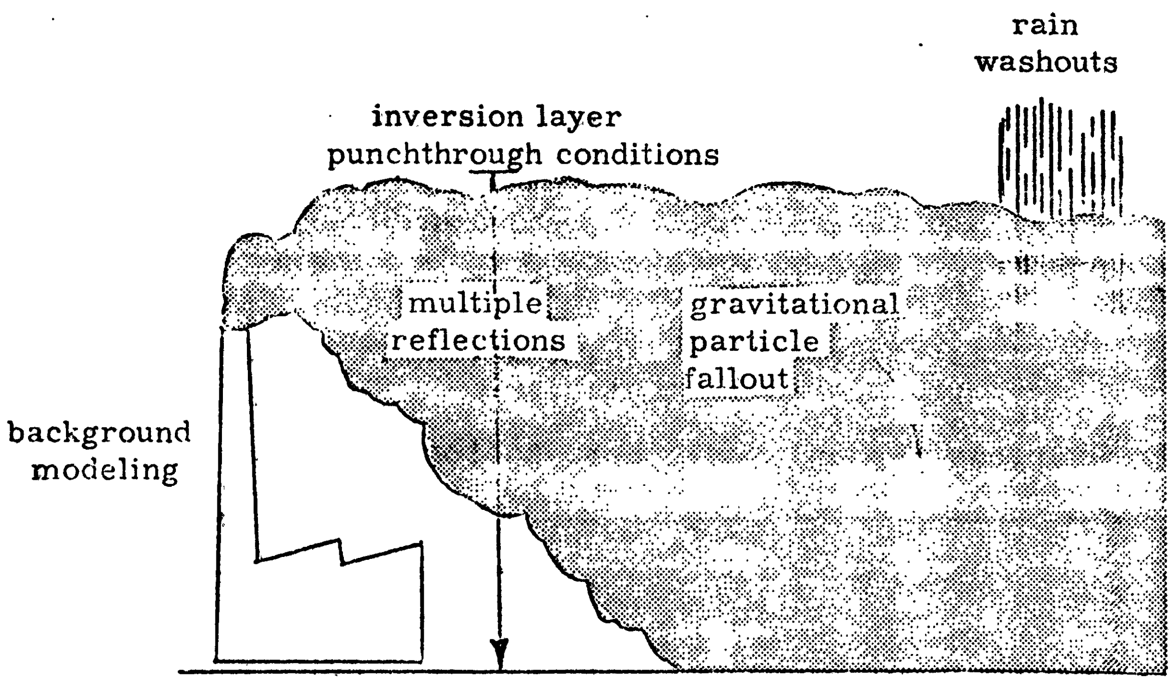
Table 3-10 Some Possible Future Directions for Improving the Fiscal Modeling in the Simulator

- variable year dollars
  1. 6% per year
  2. Handy-Whitman electric light & power extrap.
  3. Engineering News Record index extrap
- various depreciation schemes
  1. straight line
  2. sum of year's digits
  3. combination switching at given year
- insurance costs
  1. property
  2. liability
- debt/equity features
  1. debt/equity ratio
  2. annual interest rate on debt
  3. earning rate on equity
  4. bond repayment options
     - proportional
     - uniform principal reduction
     - uniform annual payment
     - uniform prin red starting at given year
- variable interest during construction
- taxes
  1. federal income tax rate
  2. state income tax rate
  3. state gross revenue tax rate
  4. property tax on plant
  5. other
- various present worth computations

Figure 5-5

Point Source Dispersion to Ambient Levels

Modified Sector-Averaged Gaussian Dispersion Model
- source superposition
- turbulence measures
- downwash modeling
- variable winds modeling
- terrain corrections
- plume slipstreaming
- mixing layer slipstreaming
- surface roughness
- variable plume rise



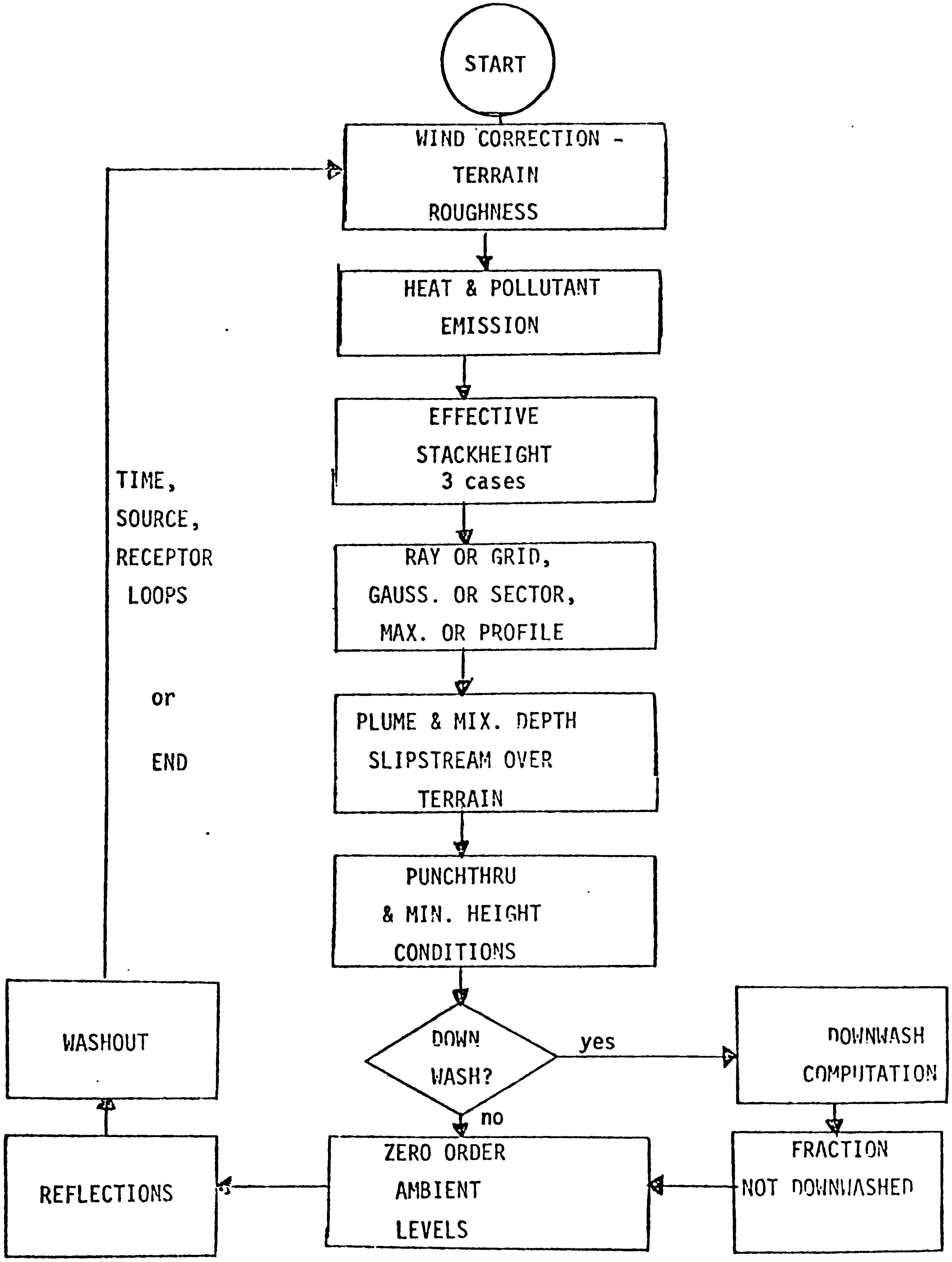


Figure 3-6 Flowchart for the Creation of Ambient Concentrations from Meteorologic and Emissions Information

is apparently no existing technique for taking time-collapsed statistics about emissions, wind speed, wind direction, mixing depth, and stability, and creating time-collapsed statistics about concentrations. The core of this problem rests in the fact that the correlations among all of these statistics is not well-known nor has it been computed. A screening model has been developed (MIT-EL 81-064WP) by project participants and personnel from EPA, but has not received peer review. Thus, in the meantime, the POLCON program is used on the STAR array hourly statistics on climatological frequency patterns, with scaling used to determine the longer averaging time concentrations. An option currently exists in the program itself that would cause these computations to take place in an aggregate generic model, and this option is standard in the current model version. A great deal more memory is needed to operate the model without this option, as in that case, dispersions are calculated and collected in detail for each population segment.

The final module of the simulator contains a wide range of different air pollution/health impact models. These models are different than anything else modeled in the simulator in that they are all deterministic. The reason for this is that they have been reported in the literature only as deterministic models. This is a serious problem in that it carries the presumption of exactness. An attempt has been made to somewhat correct for this difficulty by displaying a large number of these models, so their spread can somehow be indicative of their validity. The ideal solution to this problem would be to go back into the data used to develop these models and create the probabilistic models that should have been reported in the first place. Some research along this line has been conducted by

John Viren (Viren, 1978), and additional work along this line has been conducted as part of an MIT-Harvard Medical School contract with D.O.E. (contact J. Gruhl for further details).

3.4 AEGIS Examples

To close this brief discussion of the simulation model three simple examples will be presented, one performed by each of the co-authors in the course of the project.

The first example, shown in Figure 3-7 is a graphic display of the costs and capacities, and their uncertainties, for several different generation technologies. Although there may be other performance measures, such as annualized costs, that also must be considered in the choice among alternative generation facilities, this does show that the uncertainties are not important in sorting out desirable alternatives. Unless there is a major breakthrough forthcoming, which the simulator, of course, can not predict then wind power is the only technology that will be soon comparable to coal-fired units. Either land use or health impacts if determined tombe important by the user, would help to clearly differentiate between these two options.

Rather than just a broad look at a number of technologies, the second example shows the comparison in more detail of just two technologies. Fluidized bed combustion processes use coal ground to about pea size. This coal is fed uniformly into the combustion chamber, or bed, where air rushing in from the bottom of the combustor at about 8 feet/sec actually suspends the small pieces of coal. These suspended coal particles have the appearance of a fluid, generally seeking a particular

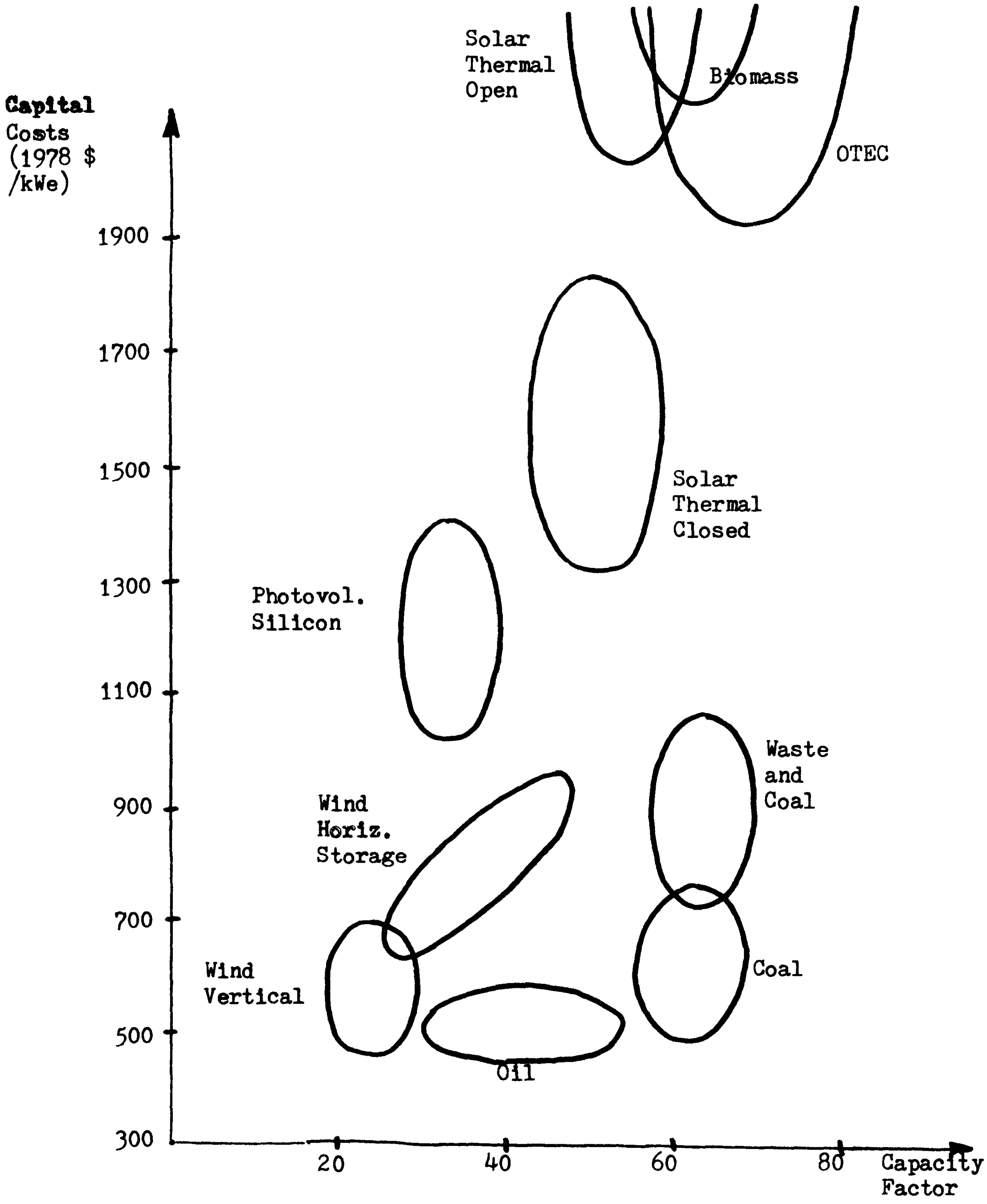


Figure 3-7 Capital Cost versus Capacity Factor comparisons from a number of AEGIS simulations

level and sometimes even displaying waves. In such a fluidized bed the coal combusts much more completely than it usually would. When the coal is burned down to the ash this ash is carried away by the fluidizing stream of air or is moved out of the bed area. A major advantage of fluidized bed is that small pieces of limestone can be introduced into the bed to absorb the sulfur oxide pollutants. Some of the uncertainties that still exist about this technology are enumerated in an EPA-sponsored report (Gruhl, Teare, 1978), and principally involve particulate control and uniform coal feeding problems.

MHD processes involve the combustion of pulverized coal at extremely high (5000°F) temperatures. At these temperatures the combustion gases ionize. When moved across a strong magnetic field electric current is drawn (onto electrodes) directly from the combustion gases. After passing through the magnetic field the gases are still hot enough to drive a conventional turbine cycle power plant. The advantage of this combined process is an extremely high efficiency, but there are still considerable problems, as listed in another EPA-sponsored report (Gruhl, 1977), including principally the slag coating of the electrodes and erosion of the turbine blades by the highly corrosive high temperature combustion gases.

For comparative purposes the conditions used to drive the AEGIS simulations of fluidized bed and MHD facilities are:

- 1900 MW size
- 1998 startup date
- West Virginia bituminous coal
- 70% design capacity factor
- 155 meter stack
- national average meteorologic conditions Indian Point 1980 population distribution, and
- LAMM - linear additive mortality model of consensus worst case health consequences of facility generated air pollution.

The MHD facility chosen was an open cycle coal fired design. The fluidized bed combustor (FBC) was of a standard, moderately pollutant-controlled design, using raw limestone #1359 as the sorbent.

Table 3-11 shows a selected set of performance measures that resulted from these simulations. For comparative purposes the middle column of Table 3-11 can be used as the value from a deterministic assessment. In every one of the deterministic comparisons there is a clear winner. However, examining the probabilistic information, with these technologies still on somewhat uncertain grounds, only in energy efficiency and respirable particulates are there clear winners. That is to say, there appears to be no chance of making a mistaken choice, i.e. where all values for one technology are superior to all values for another technology.

There are two caveats to this result. First, for two of the performance measures, investment cost and cost of electricity, there are <u>common</u> factors of uncertainty, such as cost of capital. Thus the FBC

Table 3-11 Comparison of Some Performance Measures for Fluidized Bed and MHD Facilities

		0%	16%	50%	84%	100%
Investment Cost ($Mill)	MHD	1219.8	1364.2	1529.5	2095.7	2736.0
	FBC	814.0	821.2	829.5	1088.3	1412.5
Cost of Electricity (Mills/kwh)	MHD	25.3	28.1	33.2	43.1	54.7
	FBC	20.9	22.2	24.6	30.0	36.4
Energy Efficiency (percent)	MHD	45.9	47.3	48.6	49.1	49.7
	FBC	33.5	34.4	35.6	36.8	39.9
Commercialization Year	MHD	1995	1996	1999	2003	2021
	FBC	1988	1988	1991	1995	2005
Sulfates (gm/min)	MHD	10.1	33.6	611.0	1338.	3225.
	FBC	157.8	576.3	1602.2	3504.	5662.
NOx (1000gm/min)	MHD	5.7	14.3	17.1	29.5	64.6
	FBC	15.4	20.1	25.1	32.3	37.1
Particulates Respirable (1000 gm/min)	MHD	6.0	53.2	55.1	68.4	81.7
	FBC	672.6	1311.0	1869.6	2720.8	3226.2
Polycyclic Organic Material (gm/min)	MHD	.3	.9	2.7	8.9	27.4
	FBC	3.23	66.5	164.	720.	2360.
Annual Public Health (Mortalities)	MHD	.15	1.4	4.4	9.3	14.4
	FBC	8.5	34.7	109.4	235.	404.

may in fact be certainly superior to MHD in costs once the common factors of uncertainty are investigated. Second, the respirable particulate and polycyclic organic material (POM) outputs of the FBC might be intolerable, and thus in a more detailed investigation additional particulate controls could be added at a cost. In more detailed work, the flexibility within each technology must be part of the assessment process.

In tracing back the health impacts of the technologies it turns out that the FBC particulate control will also take care of most of its health impact difference from MHD. Thus, in general, FBC is favorable from the cost and commercialization year perspectives, while MHD is far ahead in efficiency and particulate emission areas. This leaves the sulfate and NOx problems. As clear cut as the sulfate issue seems, at the level of uncertainty currently displayed by these technologies there is about a 30% chance of error from a choice of MHD as the minimum sulfate producer (a 70% chance of error choosing FBC). In investigating these emissions in terms of the regulations or the suspected health impacts it turns out there is no substantial issue here at all. Although there is great uncertainty, in neither case do the levels reach the recognition levels.

This leaves the NOx issue, which is not only becoming a health (cardiac, pulmonary, and carcinogenic) problem, and an acid rain issue (causing nearly 40% of acid rain), but unlike particulates and sulfur compounds there are no good control opportunities. Examining the emissions information, MHD is the more favorable from the deterministic (50%) point of view. However, if the decision maker is risk averse he may well decide that FBC is more favorable, particularly where the health impacts are substantially (nonlinearly) greater at higher levels.

Instead of this being a peculiar situation, it may in fact be the norm. Farther-future technologies are generally pursued because they do have an expected advantage. These technologies will, however, have much greater uncertainty, thus under risk averse decision situations they will look less favorable. This is a clear demonstration of the importance, and perhaps the necessity, of technology assessment methodologies that include measures of uncertainty.

The final example presents an even more detailed look at a single facility. Here there are a number of different types of studies that could be conducted. Perhaps the most different of these is the use of the simulator in a "detective" or reverse mode. Table 3-12 shows the range of health effects that are simulated to possibly occur due to a large MHD facility. This range covers two orders of magnitude, and for R&D planning purposes it might be useful to determine what is causing that uncertainty and how it might be resolved. Also on Table 3-12 is a list of the percentage contribution to the health impacts from each of the pollutant species. The uncertainty with regard to each of these species can then be traced back to certain ranges of parameters in the model. In the cases of nickel and beryllium the majority of the uncertainty results from a lack of information about the extent of removal of these species in the MHD combustion process (with minor contributions from uncertainties in fuel constituents, MHD efficiency, etc.). This type of use of the AEGIS model is most appropriate in that it forces the user to examine the input information, something that users should do very carefully with any model they utilize.

Table 3-12 Annual Public Health Mortalities From the 1900MWe MHD Facility Simulated

	minimum	1 dev low	median	1 dev high	maximum
BASE CASE	0.10	0.97	2.94	6.26	9.70

Percent of Base Case Range Attributible to Various Pollutants

Nickel	64.0%
Beryllium	22.1%
Particulates	5.1%
NOx	3.2%
SOx	2.9%
Arsenic	1.1%
Uranium/Radium	0.6%

4. PREDICTION OF FUTURE AMBIENT AIR QUALITY STANDARDS

It is obvious that predictions of future air quality standards, to the extent of the accuracy of those predictions, can be very valuable information. Figure 4-1 displays some of the obvious uses for such predictions, in guiding energy system decisions and in directing the pursuit of information about technologies and environmental effects. The ultimate aims of such activities can be both (1) for the optimal planning of energy system choice/use patterns, and (2) to gather information to effect the change in regulations.

This information includes highly speculative estimates of the pollutants and levels that might show up in the future federal ambient air quality regulations. The original version of this report was in the form of an oral presentation. The limited distribution of this presentation was intended to ensure that these speculations do not become self-fulfilling prophecies, that is, do not enter the regulatory decision process. This information is now sufficiently distant, 1978, so that the methodology is of much greater interest than the estimates, and thus a written summary of these results is presented here now. Although the information in this section is somewhat outdated, there are only a few new initiatives that have occurred between 1978 and 1981 that have effected the direction of standards:

- EPA recognizes air pollution to be a probabilistic quantity, but standards are absolute
  - 90% standards viewed as most rationale, but infeasible
- Probabilize standards to .1 probability of violation per year, efforts underway at EPA to construct prob. air quality models
- EPRI and other have begun to take the offensive on SO_2 regulations
- EPA is dropping all new initiatives, such as short-term NOx standards

- EPA wants to substitute Fines for TSP but wants to avoid justifying a threshold number
- Acid rain work for Congress is using ±10% controls (OTA), so utilities could take initiative in this area
- EPA wants to do cost-benefit-risk calculations for all control regulations

There were somewhat unusual mechanics involved in the preparation of these expert speculations concerning the regulatory process. The first step involved a search of the literature about the regulations, including a few articles that contained speculations about future types and extents of regulations. The second step involved interviews with about 20 experts in disciplines related to air quality. The third step included the construction and distribution of a short questionnaire with a compilation of a first set of speculations. Finally, a more extensive questionnaire was developed, see Appendix A, which contained the results of previous expert speculations and was based and interpreted in part considering the references listed in Section 5 . This questionnaire was circulated to solicit comments about the first set of speculations. Of the 120 persons asked to fill out this questionnaire, approximately 70 completed substantial portions, eight of these were paid consultants. This response rate was unusually high considering the imposing appearance of this 15-page questionnaire; it takes two to three hours to complete all 315 requests. Only a few of the more important non-responding participants were solicited more than once in the July to October 1978 period over which the final questionnaire was circulated.

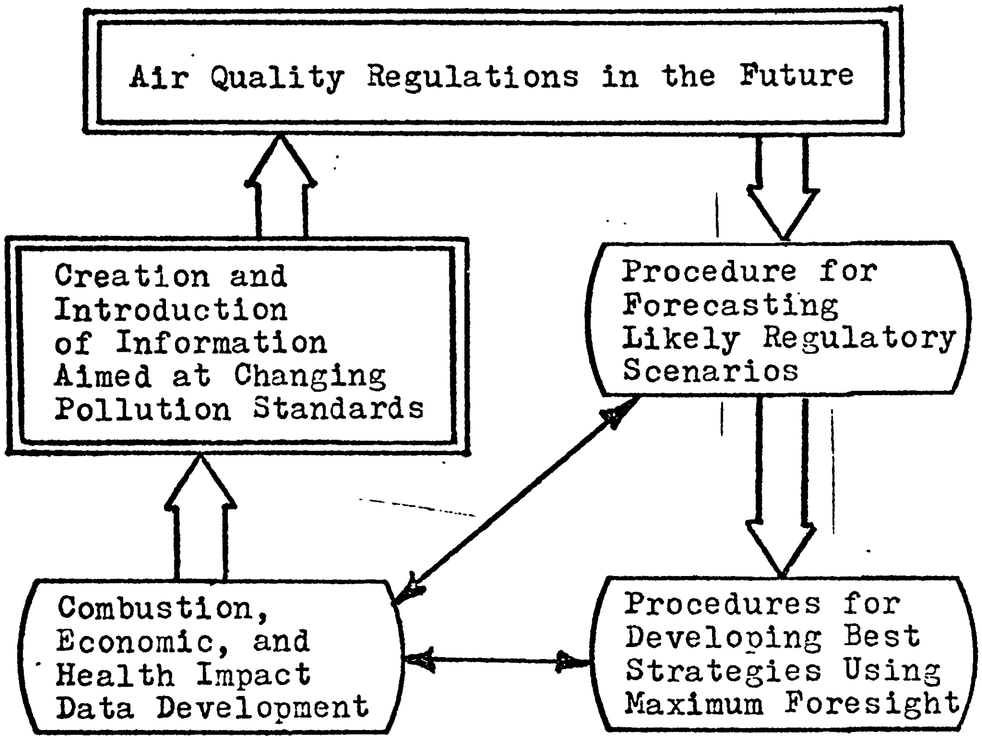


Figure 4-1 Different Types of Important Uses of Air Quality Predictions in Energy Research

Table 4-1 Disciplines Related to the Air Quality Regulatory Process

- Scientists
  - Environmentalists
  - Energy System Modelers
  - Political Scientists
  - Economists
  - Lawyers
- Engineers
  - Power System Planners
  - Power System Operators
  - Pollution Control
  - Pollution Monitoring
  - Pollution Dispersion
  - Combustion Engineers
- Health Studies
  - Epidemiologists
  - Cell and Tissue Toxicologists
  - Inhalation Toxicologists

Table 4-2 Summary of Expected Values of the Speculations About Ambient Standards

ug/m3

	1978	1983	1988	1993	1998	2003	2003
SO_2 annual	80	80	60	60	60	60	60
SO_2 24 hr	365	365	280	260	260	240	240
SO_2 3 hr	-	1300	1300	1300	1300	1300	1300
Sulfates annual	-	-	25	20	20	20	20
SO_2xPart 24 hr	-	-	500000	500000	500000	500000	500000
Part annual	75	60	60	60	60	60	60
Part 24 hr	260	150	150	150	150	150	150
RespPart annual	-	60	20	20	20	20	20
RespPart 24 hr	-	180	60	50	50	50	50
RespPart 8 hr	-	-	200	150	150	125	125
RePt x Asbest	-	-	x	x	x	x	x
CO 8 hr	10000	10000	10000	10000	10000	10000	10000
CO 1 hr	40000	40000	40000	40000	40000	40000	40000
Oxidant 8 hr	-	-	120	100	100	100	100
NOx annual	100	100	100	80	80	80	80
NOx 24 hr	-	400	400	400	400	400	400
NOx 1 hr	-	1500	1000	1000	1000	1000	1000
Nitrates annual	-	-	-	x	x	x	x
HC 3 hr	160	160	125	120	120	120	120
POM	-	-	x	x	x	x	x
Arsenic 24 hr	-	-	.15	.10	.10	.10	.10
Asbestos fbrs 24 hr	-	1200	1000	1000	1000	1000	1000
Beryllium 24 hr	-	.02	.02	.02	.02	.02	.02
Cadmium 24 hr	-	-	.05	.05	.05	.05	.05
Lead 24 hr	-	-	1.5	1.5	1.2	1.2	1.2
Mercury 24 hr	-	.30	.20	.20	.20	.20	.20
Nickel 24 hr	-	-	.03	.03	.03	.03	.03
Vanadium 24 hr	-	-	-	-	-	-	-
Radium cur/year	-	.02	.02	.02	.02	.02	.02
Pollution index	-	-	x	x	x	x	x
Carcin Cost/Ben	-	-	-	-	x	x	x

- = probably none, x = probably will be some standard

The selection of questionnaire participants was made with an attempt to get an appropriate representation of the various disciplines involved in the ambient air quality regulatory process. Table 4-1 displays a list of the disciplines that were represented among the 70 respondants. A list of the disciplines, however, does not fully capture the regulatory activities in which many of these people have been involved. These activities range from "environmental intervenors" to "consensus standard board members" to "industrial spokesmen on regulations."

Using weights that were appropriate to the professions and knowledge of the participants on each of the questions, the responses to the questionnaire were distilled by the author in a process partially documented in the remainder of this presentation. The final forecasts for federal ambient air quality standards are shown in Table 4-2.

4.1 Ambient Regulations

The principal problem with the prediction of emissions regulations is that they are generally dependent upon background concentrations, political boundaries, type, age and size of facilities, dispersion models and ambient standards, among other things. There is some evidence that bidding rights for polluting may soon take place. Such a procedure would introduce flexibility into the emissions regulations so that market mechanisms would determine the manner in which the various polluters in an airshed would control their atmospheric emissions. Although this procedure makes a great deal of sense it does make it virtually impossible to predict emissions regulations in any general manner. In this report the ambient air quality standards have thus been chosen to provide the target for prediction. This admittedly leaves many air pollution regulation issues unpredicted:

(1) state implementation plans and emissions standards,

(2) nondegradation and non-attainment questions,

(3) preconstruction reviews,

(4) tax, penalty, and variance fines as options,

(5) retrofit and best available control technologies, and

(6) exemptions and emergency episode procedures.

These predictions of ambient levels should therefore be viewed as indicators of the types and magnitudes of pollution standards. Even limited as such, these predictions can be useful in the choice of

(1) new types of generation and control equipment,

(2) new sites, and

(3) fuel types and sources.

4.2 Changing Air Pollution Standards

It is relatively well known which are the different types of forces that are acting to change the national ambient air quality standards. The magnitudes of these forces and the dynamics of their interaction, however, are not well known. For example, magnitudes are likely to change in response to a myriad of pressures. And dynamics of this process depend heavily on inertias of the regulatory and legislative decisions, inertias that will depend upon the extent of commitment to certain types of controls such as scrubbers. Regardless of the uncertainties in this regulatory process it is conceivable that a computerized model might be very useful for simulating this process. A rough attempt at a flowchart for such a model is presented in Figure 4.2.

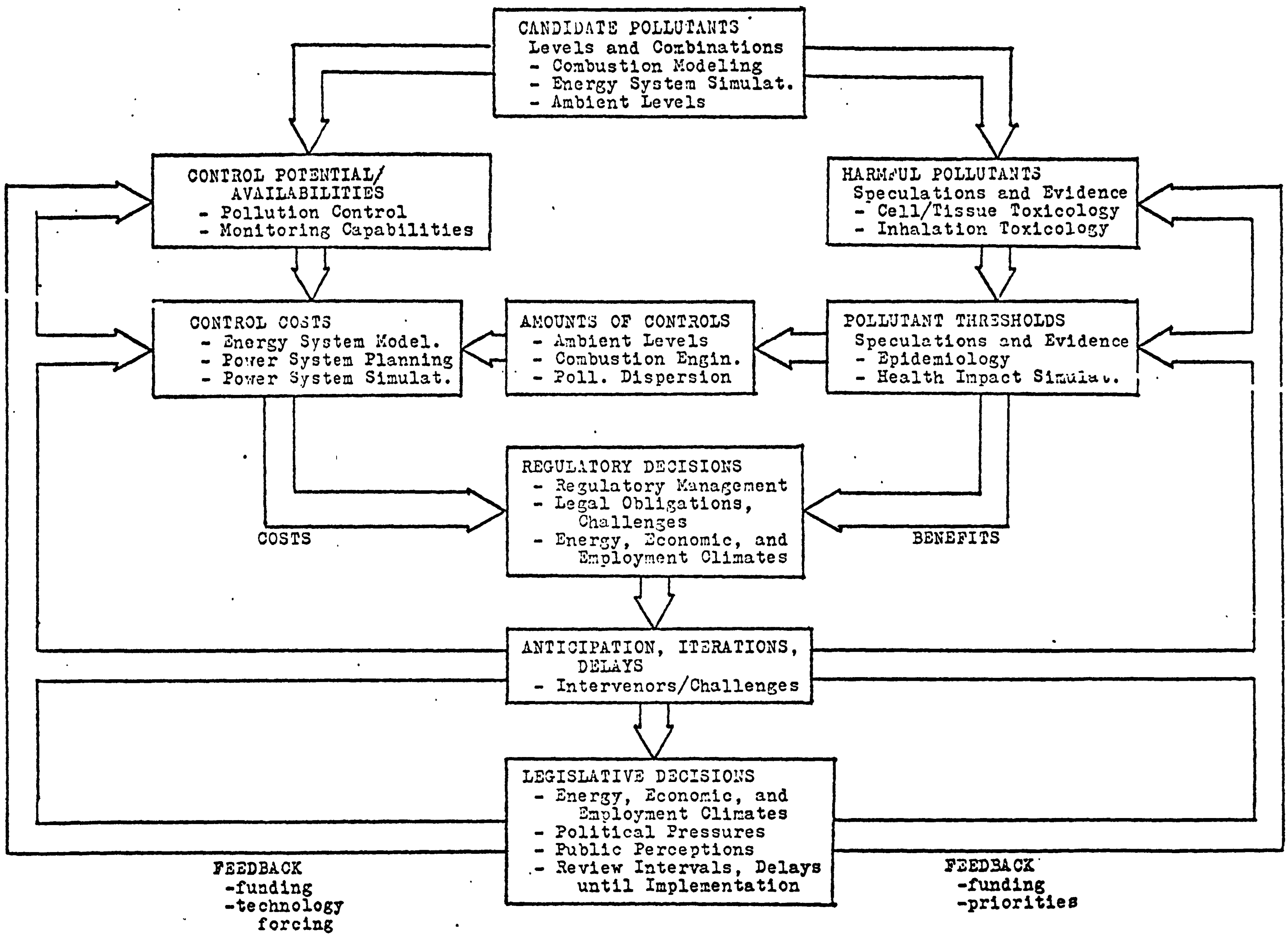


Figure 4-2 Block diagram representation of the various activities and informations that affect changes in air quality regulations.

Because of the circular nature of the lower portion of this figure, it is easiest to define a starting point with the Candidate Pollutants at the top of the diagram. Due to the tremendous variations in types of emissions due to differences in design, fuel sources, and so on, it is likely that emission and ambient regulations will constrain pollutant emissions rather than size or type of facility. Thus, the logical starting point for examining potential standards is with lists of types and magnitudes of pollutants emitted from all sources. Unfortunately there are literally thousands of such pollutants, and there is no way to simplify this initial task. However, the list of pollutants that have, and are soon likely, to be the topic of regulatory discussions is limited to those pollutants that have been identified in combustion emissions and ambient concentrations. From the box labeled Candidate Pollutants the simulation in Figure 4-2 progresses to the right side of the diagram through externalities and to the left side through internalities.

Upon information reaching the Regulatory Decision area of Figure 4-2, a number of confounding factors enter the decision process. These factors are reflections of the pressures that exist due to current energy, economic, or employment climates. In addition the path from Regulatory Decisions to Legislative Decisions will be slow and cautious, appearing to carry considerable inertia. This inertia is not necessarily a face-saving stubbornness, and delays are often due to requests for additional decision-making information, as represented by the outside pathways in Figure 4-2, or as represented in seeking readings of public perceptions of such things as:

(1) corporate obligations,

(2) regulatory burdens on standards of living, and

(3) the public's own susceptibility.

In this report there has been no attempt to computerize this type of schematic. Instead the various concerns were mentally walked through this chart, with the emphasis being placed on the right-hand side activities in Figure 4.2. The potential for a computerized model should be made clear. After some thought it appears as though the framework should be stochastic with the state variables being the extent of use of each of the various control technologies. In this way the retrofit, constraints, inertia, and life cycle considerations could be tackled in the dynamics of the state equation. The costs and benefits could then be represented by weighted, nonlinear combinations of the magnitudes of the state variables. The feedback loop then would represent the magnitudes and delays in the translation of costs/benefits to choices of control technologies. It would not be useful to force-fit this model into a type that would facilitate a closed-form optimal solution, instead it should probably be developed as a simulation model. On a much coarser scale such a model is contained within some of the world dynamics models, and it seems plausible that a more accurate simulation could be performed on a detailed segment of those models. This, however, is a potential topic for future studies, and the attention of this report now shifts to the ambient standard predictions for the specific pollutants.

Now we turn to the speculations of the experts who responded to the questionnaire, hereafter just called "experts." On the whole the expert speculation was that a relaxation of standards would be unlikely in the next thirty years. Some possible causes of relaxation would be, from least to most important:

(1) discovery of important errors in the supporting data base,

(2) discovery of better proxies or indexes,

(3) relaxation of some state or emissions standards that are now stricter than federal standards require,

(4) long-range energy system problems,

(5) short-range energy system problems, such as an oil embargo, and most importantly,

(6) economic problems.

In terms of the mechanics of the pollution standard setting process, there is currently a required review every four years. If these mechanics continue then it is the overwhelming opinion of the experts that there will probably be no more than two or three of these periods between tightening of the standards. By a more than 2 to 1 margin the experts felt that the existing BTU-input oriented emissions standards would either be rewritten or expanded to be BTU-output oriented emissions standards. The motivation for this would be to offer appropriate incentives for more efficient advanced energy facilities. One final note on mechanics, in conversions to output oriented standards or conversions to metric, 89% of the experts felt that the standards would continue to tend to be round numbers, so as to avoid the pretention of exactness.

Finally, the experts were asked to speculate about the importance of the different portions of Figure 4-2. The strengths are measured from 0 to 10, weakest to strongest, and the results are based on the 0%, 16%, 50%, 84%, and 100% points in the distribution of results from the questionnaires. Median-type statistics have been used so as to reduce the influence of outlyers. Thus the relative importance of various factors in influencing ambient air quality standards is:

(1) regional political pressure for environmental quality: 2 4 5 7 8

(2) national political pressure for environmental quality: 2 3 5 8 10

(3) regional political pressure for economic/employment: 1 3 6 7 8

(4) national political pressure for economic/employment: 0 3 5 6 10

(5) anti-"big-business" sentiment: 0 2 5 7 10

(6) EPA attempts to preserve public health: 2 3 7 9 10

(7) EPA avoidance of industrial litigation: 0 3 4 7 8

(8) legislative time delays: 0 0 1 6 8

(9) economic burden of standards: 0 2 6 8 10

(10) existing levels of pollutants: 1 2 4 8 9

(11) available pollutant control: 2 4 7 8 10

(12) available monitoring equipment: 1 4 5 7 8

(13) toxicological evidence: 1 2 5 7 10

(14) toxicological speculation: 2 3 5 7 10

(15) epidemiological evidence: 1 2 5 7 9

(16) epidemiological speculation: 4 4 5 7 10

Some additional factors that have been listed as extremely important (9 or 10) additional factors include:

(1) changes in society, such as increased strength of older American,

(2) research that EPA <u>itself</u> performs, and

(3) influences of special interest groups, such as environmentalists.

4.3 Criteria Pollutants

Sulfur received much of the initial air pollution attention because it was released in relatively larger amounts and the monitoring capabilities were more advanced than they were for other gaseous pollutants. Sulfur dioxide was initially recognized as nothing more than an index of the spectrum of air pollutants. Since then there has been an effort to associate SO_2 with health impacts, an effort to remove SO_2, and efforts to remind people that SO_2 is just an index. It has left all concerned very much polarized. It seems clear that SO_2 may never shake the implications of its long term recognition as an important air pollutant. The expert speculation on SO_2 ambient and emission regulations is:

	year:	1983	1988	1993	1998	2003	2008
SO_2 annual	100%	80	80	100	100	100	100
	84%	80	80	80	80	80	80
	50%	80	60	60	60	60	60
	16%	60	60	60	60	50	50
	0%	60	50	45	45	45	45
SO_2 24 hour	100%	365	365	365	365	365	365
	84%	365	365	365	365	300	300
	50%	365	280	260	260	240	240
	16%	260	260	260	260	200	200
	0%	240	200	150	150	150	150
SO_2 3 hour	100%	none	none	none	none	none	none
	84%	none	none	1300	1300	1300	1300
	50%	1300	1300	1300	1300	1300	1300
	16%	1300	1300	1000	1000	900	900
	0%	900	900	900	900	900	900

SOx coal-	100%	1.2	1.2	1.2	1.2	1.2	1.2
plant	84%	1.2	1.2	1.2	1.2	1.2	1.2
emissions	50%	1.2	1.2	1.0	.5	.5	.5
lb/mill BTU	16%	.6	.5	.5	.3	.3	.3
max with	0%	.2	.2	.2	.2	.2	.2
85% removal							
	100%	none	none	none	none	none	none
Sulfate	84%	none	none	30	30	25	25
annual	50%	none	25	20	20	20	20
	16%	35	20	20	18	18	18
	0%	20	15	15	15	15	15

Of the existing standards, that for which there is the most pressure to change is the 24-hour standard; next-most pressure is on a 3-hour standard. The experts judged it a slight bit more unlikely than likely that any new averaging time would be set up for SO_2. If there is a new averaging time the list from most likely to least likely is:

(1) 1 hour,

(2) 8 hour,

(3) 1 month,

(4) 4 days, and least likely

(5) 1 week.

As far as averaging time for sulfate standards thresholds, the list of most likely to least likely is:

(1) 24 hour,

(2) 4 days,

(3) 1 month, and again least likely

(4) 1 week.

Now on to some of the emission and control information. The expert speculation is to expect a 1.2 lb/10^6 BTU ceiling, 0.5 lb floor, 85%

sulfur removal, with emergency bypass allowable 3 days per month if 1.5% sulfur coal is available to be burned during bypass. It is felt that the scrubber industry is not sufficiently prepared to provide the quality and reliability of scrubbers that would be needed and that there would be great use of coal cleaning and mixing. The particulate, trace element and other benefits from scrubbers are judged about equal with the similar benefits of coal cleaning. The unreliability, on-line (versus storage) and waste products from scrubbers and judged likely to motivate the massive move to coal cleaning. If regenerable scrubber processes are not economically developed it is felt the scrubber's use will be short-lived and geographically limited. If the sulfur control issue persists past the year 2010, then gasifiers or MHD will likely remove sulfur to such an extent that it will no longer be an issue.

A question about how the long range, 100 to 500 mile, nature of the sulfate problem could be regulated brought on volumes of comments. The experts were pretty certain that there would not be regional differences in federal regulations, that is, New England and the Midwest would have the same federal regulations. This sets the stage for the problem of sulfate control, and the expert speculations included, from most to least likely:

(1) point by point emissions regulations, where source and impact area may be in different regions,

(2) overall emissions limitations, and

(3) reintroduction of intermittent control options based upon long-range sulfate projections.

The possible motivation for such controls is felt to be health impact data; acid rain by itself was felt not to be a strong enough issue to motivate such actions. Also, fog aerosols of the size to potentiate lung deposition of sulfur oxides was also thought to be an unlikely reason for either controls or episode alert activities. As far as the sulfate-to-health connection, it was felt that nitrates would probably erode much of the earlier and current importance of sulfates. Although it is pretty much conceded that there is insufficient health impact evidence for current SO_2 standards, it is probably still early enough for sulfate regulations to be pretty liberally tempered due to lack of health impact evidence. Some experts argued for the possibility of a sulfate-plus-nitrate combined standard that might regularly allow sulfate levels to exceed 30 ugm/m^3.

One final concern that was raised was that the public probably does not care (any more) about where the SO_2 levels are set. This has left the motive for the standards in the hands of regional political forces. Some of the non-health issues that will affect standards are:

(1) employment in coal production areas that have coal of different sulfur contents,

(2) local water and anti-mining efforts,

(3) coal transportation interests, and

(4) bulk power transport issues.

The responses and speculations about particulates were definitely the most startling with the most far-reaching implications. With the increased emphasis on fine particulates and the projected lack of capabilities of different control technologies, it would appear that all new coal-fired power plants built from 1990 on will have to have low-BTU gasifiers on the front end. First, here are the speculations for total suspended particulates (TSP) and for fine particulates (in ug/m^3).

	year:	1983	1988	1993	1998	2003	2003
	100%	100	100	100	100	100	100
TSP	84%	75	75	75	75	75	75
annual	50%	60	60	60	60	60	60
	16%	60	60	60	60	60	60
	0%	50	50	40	40	40	40
	100%	300	300	300	300	300	300
TSP	84%	260	260	260	260	260	260
24	50%	150	150	150	150	150	150
hour	16%	150	150	150	150	150	150
	0%	130	130	120	120	120	120
	100%	none	none	none	none	none	none
Fine	84%	none	60	60	60	60	60
particulate	50%	60	20	20	20	20	20
annual	16%	20	20	15	15	15	15
	0%	15	15	15	15	15	15
	100%	none	none	none	none	none	none
Fine	84%	none	180	180	180	75	75
particulate	50%	180	60	50	50	50	50
24-hour	16%	50	50	50	50	50	50
	0%	40	40	40	30	30	30
	100%	none	none	none	none	none	none
Fine	84%	none	none	300	300	200	200
Particulate	50%	none	200	150	150	125	125
8-hour	16%	150	125	125	125	125	125
	0%	100	100	100	100	100	100
	100%	.10	.08	.05	.05	.05	.05
New coal-	84%	.05	.05	.03	.03	.03	.03
fired	50%	.02	.02	.02	.02	.02	.02
emissions TSP	16%	.02	.02	.02	.02	.02	.02
(lb/mill BTU)	0%	.01	.01	.01	.01	.01	.01
New coal-	100%	none	.03	.03	.02	.02	.02
fired	84%	none	.02	.02	.02	.02	.02
emissions	50%	.02	.02	.02	.02	.02	.02
fine	16%	.015	.01	.01	.01	.01	.01
particulates	0%	.01	.01	.01	.01	.01	.01

A couple of points should immediately be made. First, although most agreed that 3 microns or less was the diameter of "fine particulates," some felt it could be as high as 15 microns. This might significantly change the specified levels. Second, the removal of particulates could be regulated on a percentage basis, such as 99.9% removal of TSP. Again, this is a different regulatory philosophy and these previous speculations may not be convertable for such purposes.

The feelings were almost evenly divided about whether these were the right averaging times for the particulate standards. Of those that thought there would be differences, there was no consensus, with the dominant ideas being:

(1) no 8-hour fines standard,

(2) only annual fines standard,

(3) 6-hour averaging times (correlated with visibility problems),

(4) 3-hour averages, and

(5) 1-hour average.

It was a toss-up as to whether visibility problems would contribute importantly to any decisions about the threshold levels.

A great push is seen toward the fine particulate problem; it was amazing how convinced the experts were about the eventuality of stiff fine particulate emission limitations. It seems certain that although there will be a major push toward better "fines" control techniques, that low-BTU gasifier front ends will have to take up the slack until into the beginning of the next century.

Carbon dioxide and carbon monoxide are the two air pollutants discussed in this section. First, carbon dioxide is only of concern with respect to the global heat budget and/or other climatic modification effects. The experts polled were generally uncertain of the possibility of CO_2 standards having any effects on combustion process within the next 30 years. Fewer than 1 in 5 of the experts felt sure they knew what would happen to CO_2 standards, with a very slight edge in favor of those feeling there would be no controls. Those who were uncertain leaned slightly toward "unlikely" controls; however, those claiming "probable" controls generally were from meteorological and related disciplines and claimed stronger factual bases for opinions.

On the basis of these more informed opinions the following consensus was derived:

year:	1983	1988	1993	1998	2003	2008
Chance of CO_2 Controls Affecting Energy Source Choices	0%	0%	0%	3%	10%	30%

Most experts agree that the validity of global heat balance calculations has about 30 years worth of research to go to be creditable enough for legislators. Once perceived, however, the importance of avoiding polar ice cap melting would initiate quick action toward making non-fossil alternatives more attractive and thus <u>decelerating</u> the expansion of coal-fired capacity. About twice as likely, according to the questionnaire respondants, was the possible acceleration of coal use as a means of creating more CO_2 to

(1) extend growing seasons (for additional food production), or

(2) push off start of the next glacial period.

If the CO_2 control is perceived as being very costly, there is likely to be a significant lag in requisite international agreements concerning strategies. The chance for non-energy CO_2 controls, such as additional plantings or sufficient population controls, is considered very slim.

Carbon monoxide is a localized issue, and is somewhat stronger. Amidst all of the uncertainty regarding CO, and perhaps because of it, one thing that the experts seem certain about is that there will be no relaxation of the CO standards. In any event, due to the loss of combustion efficiency represented by "unburned" carbon monoxide, there is not likely to be any effect on the design or operation of power plants. Even in the unlikely event of effects, there are common (increased temperature or excess air) and exotic (water injection or copper solution scrubbing) means of control, many of which are inexpensive.

As far as medical reasons for stricter CO standards, the medical community of experts overwhelmingly declared that even upon entering the circulatory system it was unlikely that important effects would result. There is an outside chance that cardiac disorders or some sensitive fractions of the population (sickle cell anemics) could require stricter standards. Even then the burden of control, however, would almost certainly fall on the shoulders of domestic or transportation emission sources.

Oxidants first became recognized as an air pollution problem after World War II. They are still, however, somewhat of a mystery, and still very localized in the geographic extent of the problem areas. For this reason the regulations concerning permissible levels of further deterioration and regulations concerning "nonattainment" are likely to be the most important.

As far as controls on power plant emissions to reduce ambient oxidant levels, there are several possibilities. Most likely is NOx emission controls. Hydrocarbon and particulate controls would also contribute somewhat to lower oxidant levels. Two final oxidant control possibilities presented by the experts were (1) time of day operations changes, and (2) mass transit.

The experts were spread but slightly weighted toward the likelihood that medical evidence will be forthcoming for other than nuisance problems from oxidants. The problem is apparently likely to be mutagenic effects, and regulations would likely follow close on the heels (about 1988) of the first hard evidence (possibly about 1985).

Expert speculations on the probability of various NO_2 equivalent thresholds of ug/m^3 ambient levels are:

	year:	1983	1988	1993	1998	2003	2008
	100%	100	100	100	100	100	100
NO_2	84%	100	100	100	100	100	100
annual	50%	100	100	80	80	80	80
	16%	100	80	75	75	75	75
	0%	80	50	50	50	50	50
	100%	none	none	none	none	none	none
NO_2	84%	none	800	800	500	500	500
24	50%	400	400	400	400	400	400
hour	16%	400	400	400	300	300	300
	0%	300	200	200	200	200	200
	100%	none	none	none	none	none	none
NO_2	84%	none	1500	1500	1500	1500	1500
1	50%	1500	1000	1000	1000	1000	1000
hour	16%	1000	800	700	700	700	700
	0%	500	500	500	500	500	500
New coal-	100%	.70	.60	.60	.60	.60	.60
fired	84%	.60	.55	.55	.55	.55	.55
emissions	50%	.50	.50	.50	.50	.50	.50
limit	16%	.30	.30	.30	.30	.30	.30
(lb/mill BTU)	0%	.21	.01	.01	.01	.01	.01

It is possible, but apparently not likely, that there could be different emissions limits for conventional coal combustors than for fluidized bed combustors. Grandfather clauses are likely to be quite strong in any NOx emission regulations, with the speculators heavily weighted toward the unlikelihood of NOx scrubbing being important in the next 30 years. The experts felt quite certain that NOx levels would not be allowed to rise, even if they are proved to screen out oxidant reactions.

If there is to be an NO_3 standard it is likely to be introduced at the:

(1) earliest:	1980	1983	1985	1990	1993
(2) likeliest:	1982	1985	1990	1998	2020
(3) latest:	1984	1987	1995	2003	2030

More than two-thirds of the experts felt that NO_3 standards, if they do come, would be set on the basis of health impact information. Most of the others thought it might come as a result of some other need to reduce ambient levels.

Based on a 0 to 10 score, the experts judged how strongly they felt that public pressure for NOx controls would be if any of the following problems could be correlated to NOx:

(1) reduced visibility:	2	3	7	9	10
(2) eye irritation:	1	2	7	8	10
(3) slightly increased mutations:	4	5	5	8	10
(4) slightly increased cancer rates:	3	5	6	9	10
(5) nervous disorders:	1	3	4	7	9

What seems significant here is that although the medical community gave low marks to the first two problems, in mass the feeling of the experts was that these instantaneously realized problems would result in greater public pressure. All of the experts agreed it would be unlikely or impossible that NOx would be significantly correlated with mutations to result in any control actions. The unlikely possibility of control would probably be based upon a linear extrapolation of effects down at low levels.

4.4 Other Pollutant Regulation Issues

The real issue with the hydrocarbons is the fact that some hydrocarbons are inert, some very toxic, and thus they should not be lumped together. The experts feel that the monitoring problems can be handled and that hydrocarbons will be split into three categories based upon the toxicity of benz(a)pyrene, (BaP):

(1) less than .01 BaP,

(2) between .01 and .10 BaP, and

(3) more toxic than .10 BaP.

The constraint on hydrocarbon emissions would likely be an operating constraint rather than a licensing constraint, and would be instituted in the year:

(1) earliest:	1982	1983	1985	1990	2010
(2) likeliest:	1985	1985	1988	1995	2020
(3) latest:	1987	1990	1993	2000	2030

There is a likely chance than some organic sulfur and nitrogen compounds will be connected to human cancer rates. A carcinogenic cost/benefit analysis was judged unlikely by the experts, but personally I very much disagree. If there is such an analysis required in the licensing requirements of new coal plants it would come in the year:

(1) earliest:	1980	1982	1985	2000	2015
(2) likeliest:	1981	1985	1990	2020	2030

(3) latest: 1983 1990 2000 2030 2045

Retrofit cost/benefit analyses and controls were also judged unlikely. If such analyses, of new or existing plants, do take place, the number of excess mortalities that would be balanced against 1000 MW was judged to be: 0, .1, 3.5, 50, 100.

The trace elements are the other class of air pollutants treated in this section. It is possible that the different trace elements might be combined into a single index or cost/benefit analysis. This was judged unlikely by the experts, with separate regulations the most likely. The averaging times for these elements, from most likely to least likely, was speculated as being:

(1) 24 hours,

(2) 1 month,

(3) 3 days,

(4) 1 year, and least likely,

(5) 1 week.

For some time now the community of scientists studying health impacts have called for threshold standards on combinations of pollutants. Each air pollutant has a common target area in the body, the lungs, and to some extent acts either synergistically or additively with other pollutants. The experts were strongly convinced that combination standards would be in force in the next 30 years. The principal problem with such "indexes" is that they are difficult to substantiate, more difficult to enforce, and almost impossible for which to develop control strategies. In fact the only likely way of dealing with such control situations is to let the marketplace price the various pollutant control options. Experts from the regulatory community claim the pressure is now off for an index. The rest of the expert communities, in response to the 1977 Clean Air Act amendments which call for the study of some index, feel that a national index could come:

(1) earliest:	1979	1980	1982	1985	1986
(2) likeliest:	1980	1983	1988	1990	2010
(3) latest:	1981	1985	1990	2000	2020

Almost all of the experts agreed that a national index would have to be sufficiently flexible for tuning to a variety of locations, pollutants, and local political pressures. All agreed that no such index was now available. There is a fair chance that the index will be of a linear additive form.

The most likely combined <u>standard</u> would be the one now in use in California: SO_2 times particulates less than 4.9×10^5 ugm^2/m^6. If the federal index is to be of this form it will likely be

(1) in year:	1985	1985	1988	1990	1993
(2) at level:	3.0	4.9	5.0	5.0	6.0

times $10^5 ugm^2/m^6$. The principal fault with this standard, as discussed by the experts, was that either the particulates should be replaced by fine (or respirable) particulates or such a category should be a third term in the multiplication.

Other combinations of pollutants that were proposed by the experts as likely included:

(1) SO_2, particulates and oxidants,

(2) sulfates plus nitrates,

(3) respirable particulates times asbestos, and

(4) NOx times hydrocarbons.

As far as the possibility within the next 30 years of an NOx times hydrocarbon threshold standard, only 21% of the experts felt this would be likely. On the issue of asbestos times respirable particulates, the control is likely to fall on asbestos sources. About 36% of the experts expect such a standard. They feel it would not be as strict as 1.5 x 10^6 fibers ugm/m^6 over 24 hours. If such a combined standard comes about it would likely be in the year: 1983, 1985, 1988, 1990, 1993.

Earlier in the air pollution regulatory process, some of the state or local ideas about levels of standards were important indicators of national trends. The opinion is that this was due primarily to the relatively easier task of reading the desires of a local population and the faster dynamics in the local political process. This is no longer as much the case, partly due to the resource requirements of court fights with local industries.

At this point in time, the only important trend indicator that was identified by the experts was the trend in the air pollution protections required in occupational environments. There has been a sharp increase in the number of criteria documents developed by NIOSH, from 23 to 88 total criterial documents, and the experts feel this trend will moderate only slightly. This increase is seen as moderately important in signalling new air pollution standards. Much of the tremendous push still to come in workplace safety, and perhaps also in public safety, will be due to new data on carcinogenic pollutants. In addition, rated 0 to 10 by strength, the other important factors that will affect workplace air standards are:

(1) Democratic party control of OSHA:	2	4	5	7	10
(2) labor group pressures:	2	5	7	9	10
(3) better monitors and information:	3	4	8	10	10
(4) general public pressure:	2	4	4	8	10
(5) anti-"big business" forces:	0	2	3	5	9
(6) economic/employment climate:	2	7	8	9	10

One final comment on a factor of importance was that insurance companies were beginning to be a strong and insistent force in favor of stricter occupational standards. It is possible, but unlikely, that they would take a leading role in pressuring for stricter public health protection from air pollutants.

5. REFERENCES AND BIBLIOGRAPHY

Ahmed, Husseiny, A.A., 1978. "Multivariate-Utility Approach for Selection of Energy Sources," Energy (Oxford), v.3, n. 6., December, pp. 669-700.

Andrew, G.H.L., 1954. "Assessing Priorities for Technical Effort," Operational Research Quart, v. 5, pp. 67-80, September.

Ascher, W., 1979. "Problems of Forecasting and Technology Assessment," Technological Forecasting and Social Change, v. 13, pp. 119-156.

Arnstein, S.R. and A.N. Christakis, 1975. "Perspectives on Technology Assessment," Science and Technology Publishers.

Arnstein, R., 1977. "Technology Assessment: Opportunities and Obstacles," IEEE Trans Syst Man Cybern, v. SMC-7, n. 8, August, pp. 571-582.

Ayres, R.U., 1969. Technology Forecasting and Long-Range Planning, New York, McGraw-Hill Book Company.

Ayres, R.U., A. Shapanka and K. Humes, 1972. Priorities for Technology Assessment, prepared for the Office of Exploratory Research and Problem Assessment, National Science Foundation. Washington, DC, March 16.

Baes, C.F., Jr., H.E. Goeller, J.S. Olson, and R.M. Rotty, 1976. "The Global Carbon Dioxide Problem," ORNL-5194, August.

Baker, R., 1974. "R&D project Selection Models: An Assessment," IEE Trans Eng Manage, v. EM-21, n. 4, November, pp. 165-171.

Bareano, P., 1972. A Possible Methodology for Technological Assessment, Occasional Paper α30, Cornell Program on Science, Technology, and Society, March.

Beller, M. et al., 1979. "Impacts of new energy technologies as measured against reference energy systems," (BNL-25475).

Bereano, J., 1971. "Technological Planning: Assessment and Adversarial Participation," Thesis presented to Cornell University, January, pp. 113-210. H.

Bereano, P.L. et al., 1973. "A Proposed Methodology for Assessing Alternative Technologies," Technology Assessment, v. 1, no. 3, pp. 179-190.

Berg, M., K. Chen, G. Zissis, 1976. "Value-Oriented Policy Generation Methodology for Technology Assessment," Technol Forecasting, v. 8, n. 4. pp. 401-420.

Black, G., 1971. Technology Assessment--What Should It Beµ, Staff Discussion Paper α211, The George Washington University, Washington, DC, June.

Breslow, M., et al., 1972. A Survey of Technology Assessment Today. PB 221-850, NTIS, Springfield, VA, June.

Bright, R., editor, 1968. Technological Forecasting for Industry and Government, Englewood Cliffs, NJ, Prentice-Hall, Inc.

Brock, H.W. and D.M. Nesbitt, 1977. "Large Scale Energy Planning Models: A Methodological Analysis," Stanford Research Institute, Menlo Park, CA, May.

Broecker, W.S., Takahashi, T., Simpson, H.J., Penz, T.H., 1979. "Fate of Fossil Fuel Carbon Dioxide and the Global Carbon Budget," Science, 206, 4417.

Brooks, H., and Bowers, R. 1970. "The Assessment of Technology," Scientific American, vol. 222, no. 2, February, pp. 13-21.

Buehring, W.A., W.K. Foell, and R.L. Keeney, 1978. "Examining Energy/Environmental Policy Using Decision Analysis." Energy Systems and Policy, 2 (3), pp. 341 - 367.

Burnett, R.A. and D.W. Fraley, 1977. "Description and Comparison of Energy Impact Assessment Models." Battelle, Pacific Northwest Laboratories, BNWL-2107, UC-11, April.

Carpenter, R.N., 1973. "The Scope and Limits of Technology Assessment," Technology Assessment, v. 1, n. 1, pp. 41-46.

Cetron, Marvin J., 1969. Technological Forecasting: A Practical Approach, New York, Gordon a Breach.

Cetron, M., and Bartocha, B., 1973. The Methodology of Technology Assessment, Gordon and Breach, New York.

Cetron, M., and Connor, L., 1973. "A Method for Planning and Assessing Technology Against Relevant National Goals in Developing Countries," in The Methodology of Technology Assessment, M. Cetron and B. Bartocha, eds., Gordon and Breach, New York, pp. 1-32.

Cetron, M., 1973. "The Trimatrix--An Integration Technique for Technology Assessment," in Technology Assessment in a Dynamic Environment, M. Cetron and B. Bartocha, Ed., Gordon and Breach, New York, pp. 673-708.

Chen, F., 1974. Introduction to Plasma Physics, Plenum Press, New York.

Chen, K., 1979. "International Perspectives on Technology Assessment," Technology Forecasting Soc Change, v. 13, n. 3, April, pp. 213-233.

Chen, K. and G. Zissis, 1973. "Philosophical and Methodological Approaches to Technology Assessment," presented at the First International Congress of Technology Assessment.

Chen, K. et al., 1977. "Energy R and D modeling for budgetary decisions," IEEE TRans. Syst., Man, Cybern.; SMC-7: No. 4, 222-227 (April 1977).

Cheremisinoff, P.N., and A.C. Morresi, 1976. "Geothermal Energy Technology Assessment," Geotherm Energy Technol Assess Publ by Technomic Pub Co, Westport, CT, p. 164.

Cloutier, P.D., J.G. McGowan, W.P. Goss, 1975. "Preliminary Technology Assessment: Ocean Thermal Energy Conversion Systems," ASME Pap no. 75-WA/TS-3 for Meet Nov 30-Dec 4, 16 pp.

Coate, D.E., 1980. "Uncertainties in Energy Technology Assessments," MIT Energy Lab, Report MIT-EL 80-013, 120pp., June.

Coates, J., 1974. "Some Methods and Techniques for Comprehensive Impact Assessments," Technology Forecasting and Social Change, no. 7, pp. 341-357.

Coates, J.F., 1974. "TA's Impact on Engineering Practices," SME Tech Pap n MM74-158 for Meet, Apr 29-May 3, 11 pp.

Coates, J., 1974. "Some Methods and Techniques for Comprehensive Impact Assessments," Technology Forecasting and Social Change, vol. 6, no. 4, pp. 341-357.

Coates, V., 1972. "Technology and Public Policy, The Process of Technology Assessment in the Federal Government," Vols. I-III, PB 211-453 to PB 211-455, NTIS, July.

Coates, T., 1973. "Future Directions for Technology Assessment," IEEE Intercon Tech Pap for Meet, New York, NY, Mar 26-30, v. 7, Pap 35/1, 1 p.

Coates, V.T., 1973. "Technology Assessment -- Where It Stands Today," Res. Manage., v. 16, n. 5, Sept. pp. 12-17.

Coates, V.T., 1978. "Handbook of Technology Assessment. Final Report, Vol. I" SCE 1978 (TID-28503).

Cohen, A.S. and K.W. Costello, 1975. "Alternative Approaches to Energy Modeling." Argonne National Laboratory, Energy and Environmental Systems Division, Argonne, IL.

Cohen, A.S. and K.W. Costello, 1975. "Regional Energy Modeling: An Evaluation of Alternative Approaches." Argonne National Laboratory, Regional Studies Programs, ANL/AA-1, June.

Connolly, T., 1975. "Communication Nets and Uncertainty in R&D Planning," IEEE Trans Eng Mange, v. EM-22 n. 2, May, pp. 50-54.

Cook, P.L., et al., 1977. Energy Policy: Strategies for Uncertainty, Martin Robertson and Co. Ltd.

Cooper, D.E. and W.C. Hamilton, 1979. "Atmospheric Sulfates and Mortality—The Phantom Connection," Continental Oil Company, Pittsburgh, PA.

CRA, 1978. "State-of-the-Art Review of Large-Scale Energy Models." Charles River Associates, Cambridge, MA.

Darvas, J., Tritium Technology in Fusion Devices, Kernforschungsanlage Julich, Federal Republic of Germany.

Darvas, J., 1975. "Progress in Assessing the Technological Problems of Fusion Reactors," Eur Nucl Conf, Proc: Nucl Energy Maturity, Paris, Fr, Apr 21-25, v. 1, pp. 68-80, Publ by Pergamon Press, New York, NY.

David, E.E., 1971. "Some Questions on the Role and Effectiveness of Technology Assessment," Res Mange, v. 14, n. 2, March, pp. 21-3.

Eldredge, R.W., et al., 1974. "Pollution Control Technology Assessment: Procedings of an Environmental Resources Conference," Pollut Control Techno Assess, Proc of Enviro Resour Conf. Pap, Columbus, Ohio, May 1-3 Publ by Natl Environ Res Cent (EPA-670/9-74-006), Cincinnati, Ohio, p. 190.

Electric Power Research Institute, 1978. "Pollution in Public," EPRI Journal, pp. 21-27, October.

Enzer, S., 1972. "Cross-Impact Techniques in Technology Assessment," Futures, v. 4, n. 1, March, pp. 30-51.

Erickson, L.E., et al., 1978. "Usefulness of alternative integrative assessment methodologies in public decision making." (PNL-RAP-24).

Fay, J.A. and J.J. Rosenzweig, 1980. "An Analytic Diffusion Model for Long Distance Transport of Air Pollutants," Atmospheric Environment, 14, pp. 355-365.

Federal Register, 1976. "Health Risk and Economic Impact Assessments of Suspected Carcinogens," FR 401-102, p. 21402, May 25.

Finsterbush, K., et al., 1974. "A Methodology for the Analysis of Social Impacts," Report No. BDM/W-74-049-TR, Braddock, Dunn and McDonald, Inc.

Fischer, D.W., 1977. "Assessing the development decision-making parocess: a holistic framework." Am. J. Econ. Sociol.; 36: No. 1, 1-18, Jan.

Fritsch, A.J.; 1973. "Technology Assessment: The Citizen's Role," ASME Pap n 73-WA/TA-1 for meet, Nov 11-15, 7 pp.

Fusfeld, A., 1970. "The Technological Progress Function--A New Tèchnique for Forecasting," Technology Forecasting, Vol. 1, No. 3, Mar., pp. 301-312.

The Futures Group, 1975. "A Technology Assessment of Geothermal Energy Resource Development," Prepared for the National Science Foundation, April 15, 1975, pp. 554, U.S. Government Printing Office 038-000-00233-3.

Garg, D., 1974. "The Process of Technology Assessment," Proceedings of the Sixth Annual Southeastern Symposium on System Theory, Paper No. FP-5.7, Feb.

Garg, D.P., 1975. "Technology Assessment and Social Choice: A Policy-Oriented Course," ASME pap n 75-WA-TS-2 for Meet Nov 30-Dec 4, 7 pp.

Garg, D.P., 1976. "Comprehension of Societal Impacts via Technology Assessment," J Dyn Syst Mes Control Trans ASME v. 98 Ser G, n. 1 March pp. 52-62.

Garrett, D.E., 1977. "Pinpointing the Needs in Research and Development," Chem Eng (NY), v. 84, n. 12, Jun 6, pp. 146-149.

Golay, M., 1979. "Environmental Impacts of Electric Power Production," MIT Course Notes, Cambridge, MA.

Goldberg, A.J., 1973. "Survey of Emissions and Controls for Hazardous and Other Pollutants," EPA, NTIS #PB-223 568, Springfield, VA.

Gordon, R.L., 1978. "The Hobbling of Coal: Policy and Regulatory Uncertainties," Science, 200, p. 153, April 14.

Gordon, T.J., and Ament, R.H, 1969. "Forecasts of Some Technological and Scientific Developments and Their Societal Consequences," Report R-7, The Institute for the Future, Middletown, September.

Gordon, T., and Becker, H., 1972. "The Use of Cross-Impact Matrix Approaches in Technology Assessment," in The Methodology of Technology Assessment, M. Cetron and B. Bartocha, Ed., Gordon and Breach, New York.

Gordon, T., 1974. "A Discussion of Some Methods of Technology Assessment," Report No. 138-01-17, The Futures Group0, Glastonbury, Conn., Apr.

Green, P., 1972. "The Adversary Process in Technology Assessment," in R. Kasper, Ed., Technology Assessment: Understanding the Social Consequences of Technological Applications, pp. 49-70.

Greenberger, M., 1977. "Closing the circuit between modelers and decision makers." EPRI J.; 2: No. 18. 6-13, Oct.

Gruhl, J., 1977. "Coal-Fired Open Cycle Magnetohydrodynamic Power Plant Emissions and Energy Efficiencies," MIT-EL 78-018, 147 pp., November.

Gruhl, J., 1978. "AEGIS—Alternative Electric Generation Impact Simulator," MIT-EL 79-010, MIT Energy Lab, Cambridge, MA.

Gruhl, J., Sept. 1978. "Speculations about Future Ambient Air Quality Regulations," MIT Energy Lab, Informal Notes, September, 52pp.

Gruhl, J., 1978. "Predictive Qualities of Environmental Information in Energy Models," Proceedings Integration of Environmental Considerations into Energy-Economic Models, EPRI Special Report, 42pp, October.

Gruhl, J., 1979. "Setting Noneconomic Information into Energy Decision Frameworks," EPRI Report WS-95, p. 2-1 to 2-14, October.

Gruhl, J. and N.H. Gruhl, 1978. "Methods and Examples of Model Validation - An Annotated Bibliography," MIT Energy Lab Working Paper MIT-EL 78-022WP, July.

Gruhl, J., F.C. Schweppe, M.F. Ruane and S. Finger, 1976. "Systematic Methodology for the Comparison of Environmental Control Technologies for Coal-Fired Electric Generation," MIT Energy Lab Report MIT-EL 76-012 for DOE Contract W31-109-Eng-38, pp. 216, November.

Gruhl, J. and A.E. Sotak, 1978. "Comparing Advanced Energy Cycles and Developing Priorities for Future R&D," MIT Energy Lab Report MIT-EL 78-030, 54 pp., A ugust.

Gruhl, J., F. Speizer, W. Maher, J. Samet, M. Schenker, 1979. "Evaluation of Health Effects of Air Pollution in the Chestnut Ridge Area," DOE Report COO-4968-1, October.

Gruhl, J. and J.D. Teare, 1977 "Empirical Models of Emissions and Energy Efficiencies of Coal-Fired Fluidized Bed Power Plants," MIT-EL 78-015, 319 pp., September.

Haden, C.R., 1978. "Regional Power System Planning: A State of the Art Assessment, Interim Report - Survey of Planning Models." USDOE, MCP/T-5468/1, January.

Hetman, F., 1973. "Society and the Assessment of Technology," Organization for Economic Cooperation and Development, Paris, France, p. 109.

Hetman, F., 1975. "Methodological Guidelines for Social Assessment of Technology," Organization for Economic Cooperation and Development, Paris, France.

Hinkle, F.J., J.M. Armstrong, 1975. "Environmental and Socioeconomic Impacts of Western Energy Development -- The Role of Technology Assessment in Energy Policy," Energy and Environ, 3rd Natl Conf, Proc, Hueston Woods State Park, Ohio, Sep 29-Oct 1 1975 pp. I-12, Publ by AIChE, Dayton and Ohio Valley Sect, New York, NY.

Holden, C., 1976 "Bill Revising Clean Air Act...," Science, 194, p. 406, October 22.

Holland, W.E.; Stead, B.A.; Liebrock, R.C., 1976. "Information Channel/Source Selection as a Correlate of Technical Uncertainty in a Research and Development Organization," Univ of Houston, Tex, IEEE Trans Eng Manage, v. EM-23, n. 4, Nov., pp. 163-167.

Hollomon, J., et al., 1975. Energy Research and Development, Cambridge, Mass., Ballinger Publishing Co.

Hoos, I.R., 1979. "Societal Aspects of Technology Assessment," Technol Forecasting Soc Change, v. 13, n. 3, Apr, pp. 191-202.

Humes, K.H., et al., 1974. "Determining Priorities for Technology Assessment," Technology Assessment, v. 2, n. 2, pp. 145-157.

Jantsch, E., 1967. Technological Forecasting in Perspective, Paris, Organization for Economic Cooperation and Development.

Jones, M.V., 1972. "The Methodology of Technology Assessment," The Futurist, Feb. p. 20.

Jones, M., 1973. "The Methodology," Technology Assessment, Vol. 1, No. 2, pp. 143-151.

Jones, M., 1973. "A Comparative State of the Art Review of selected U.S. Technology Assessment Studies," PB 222-370, NTIS, Springfield, VA, May.

Kabele, T., Johnson, A., Mudge, L., Definition of Source Terms of Tritium Evolution from CTR Systems, Battelle Pacific Northwest Laboratories.

Kasper, R., 197 8. Technology Assessment: Understanding the Social Consequences of Technological Applications, Praeger Publishers, New York, Jan.

Kaserman, D.L., 1978. "Methodological Note on the Evaluation of New Technologies: The Case of Coal Gasification," Energy (Oxford), v. 3, n. 6, Dec, pp. 737-745.

Kawamura, K.; Boroush, M., Chen, K.; Christakis, N., 1979. "Design for a Technology Assessment of Coal," Futures, v. 11, n. 4, Aug 1979, pp. 299-311.

Keeny, S.M., et al., 1977. Nuclear Power Issues and Choices, Ballinger Publishing Co.

Kiefer, D., 1970. "Technology Assessment," Chemical and Engineering News, Vol. 48, No. 42, Oct. 5, pp. 42-56.

Kiefer, D.M., 1973. "Technology Forecasting in Technology Assessment," Technology Assessment, v. 1, n. 2, pp. 137-141.

Kirchmann, R., et al., 1977. "Consensus," (Centre d'Etude de l'Energie Nucleaire, Mol, Belgium, no. 1, pp. 29-38.

Lanthrop, J.W., 1977. "Value of time in energy R and D Planning," UCRL-80337.

Leistritz, F.L., et al., 1977. "The REAP Economic-Demographic Model: Background, Structure, and Applications." North Dakota Regional Environmental Assessment Program.

Leonard, R.L., 1977. "Methodology and Preliminary Results of a Technology Assessment of Western Energy Development," Pac Chem Eng Congr (PAChEC '77), 2nd, Proc. Denver, Colo, Aug 28-31 1977 Publ by AIChE, New York, NY, V. 2, pp. 1366-1371.

Lewis, D.B., Jr., 1977. Trans Annu Tech Conf ASQC 31st, Philadelphia, Pa, May 16-18 1977, Publ by ASQC, Milwaukee, Wis, pp. 197-301.

Limaye, D.R., 1976. "Energy Policy Evaluation Modeling and Simulation Approaches." Journal of the American Institute of Planning, 42 (3), p. 352.

Limaye, D.R., F. Ciliano, and J.R. Sharks, 1972. "Quantitative Energy Studies and Models: A State of the Art Review." Decision Sciences Corporation.

Linke, S., 1973. "Major Issues of a National Energy Research and Development Program," a Report of the Workshops organized by Cornell Univ., Ithaca, NY, Dec.

Lock, G.S.H., 1973. "Developing Responsibility of Technology Assessment," Eng J. (Montreal) v. 56, n. 9 Sep, pp. 18-22.

MacMahon, B., 1980. "Epidemiology's Strengths, Weaknesses in Environmental Health Issues," National Academy of Sciences, News Report, April, pp. 5-7.

Maimon, S.R., 1973. "Practical Considerations in Forecasting and Assessment," IEEE Intercon Tech Pap for Meet, New York, NY, Mar 26-30, v. 7, Pap 35/5, 4 pp.

Martin, D., 1978. "EPA Ponders Letting Concerns Buy and Sell 'Right' to Pollute Air," Wall Street Journal, December 15.

Massachusetts Energy Facilities Siting Council, 1978. "An Integrated Regional Approach to Regulating Energy Facility Siting." U.S. Nuclear Regulatory Commission Report, NUREG/CR-0241. Vol. 1 and 2, June.

Mayo, L., 1969. The Management of Technology Assessment, George Washington University, Washington, DC, Apr.

Mayo, L., 1970. Scientific Method, Adversarial System, and Technology Assessment, Monograph α5, The George Washington University, Washington, DC, Nov.

Mayo, L., 1971. The Contextual Approach to Technology Assessment, Monograph α9, the George Washington University, Washington, DC, April.

McDonald, G.C. and R.C. Schwing, 1973. "Instabilities of Regression Estimates Relating Air Pollution to Mortality," Technometrics, 15, pp. 463-481.

McKay, M.D., 1978. "Sensitivity analyis techniques: a case study," LA-7549-M5.

Michael, D.N., 1978. "Technology Assessment in an Emerging World," Technol Forecasting, v. 11, n. 3, Mar, pp. 189-195.

Mills, E.S., 1978. "Auto Emissions: Why Regulation Hasn't Worked," Technology Review, p. 55, March/April.

Mills, M.T., Lee, R.F., 1980. "Critical Meteorological Conditions for Elevated 3-Hour and 24-Hour SO_2 Concentrations in the Vicinity of Coal Fired Power Plants," Teknekron Research Inc., Waltham, MA, (forthcoming).

NASA, 1976. "Comparative Evaluation of Phase One of the Energy Conversion Alternatives Study," NASA-Lewis Labs Report TM X 71855, February.

Nisbet, I.C.T., 1978. "Flaws and Failures of the Clean Air Act," Technology Review, p. 10, March/April.

Nordhaus, W.D., 1979. The Efficient Use of Energy Resources, New Haven and London, Yale University Press.

Oberbacher, B., 1976. "Investigations of the technical, organisational, and social preconditions for risk strategies in the field of technological development. Intermediate report 200/1: comparing the health risk connected with different electric power generation technologies," BF-R-62530-200/1.

Oberkampf, V., 1978. "Technology Assessment: Need and Motivation of Industry, Long Range Planning, v. 11, n. 4 Aug, pp. 48-57.

Okrent, D., et al., 1977. "An approach to societal risk acceptance criteria and risk management," PB-271264.

Palmedo, P.F., 1976. "Energy technology assessment: considerations of geographic scale," BNL-21663.

Park, S. Polich Anal Inf Syst v. 2, n. 2 Jan 15 1979, pp. 121-126.

Piet, S., 1979. Uncertainties in Modeling of Tritium Hazards from Fusion Reactors, M.S. thesis, MIT Nuclear Engineering, Cambridge, MA.

Raiffa, H., 1968. Decision Analysis: Introductory Lectures on Choices Under Uncertainty, Addison-Wesley, Reading, Mass.

Ricci, P.F., and R.E. Wyzga, 1979. "Review of Epidemiological Studies of Air Pollution: Statistical Emphasis," National Commission on Air Quality, November 7.

Roessner, J., 1974. Methodology for Technology Assessment, Technol Forecasting, v. 6, n. 2 p 163-169.

Rose, D.J., 1980. "On the Global CO_2 Problem," statement to the U.S. Senate Committee on Energy and Natural Resources. April.

Rossini, F.A., et al., 1975. "Multiple Technology Assessments," Presented at the Meeting of the International Society for Technology Assessment in the Hague.

Rotty, R.M., 1979. "Uncertainties Associated with Global Effects of Atmospheric Carbon Dioxide," Institute for Energy Analysis Occasional Paper, ORAU/IEA-79-6(O), March.

Rowe, W.D., 1973. "Technology Assessment and Its International Implications," Jt Eng Manage Conf, 21st Annu, St. Petersburg, Fla, Oct 25-26 p 29-33. Publ by ASME, New York, 1973.

Rubenstein, A.H., 1957. "Setting Criteria for R&D," Harvard Business Review, pp. 95-104, January-February.

Sahal, D., 1977. "Structural Models of Technology Assessment," IEEE Trans Syst Man Cybern, v. SMC-7, n. 8 Aug., pp. 582-589.

Scientific Committee on Problems of the Environment (SCOPE), 1976. "Environmental Modeling and Decision Making, The U.S. Experience." Holcomb Research Institute, Praeger Press, NY.

Selman, J.H.N. and V. Selman, 1973. "Technology Assessment: State-of-the-Art and Credibility 1973," Summer LComput Simulation Conf. Proc. Montreal, Que, Jul 17-19, v. 2, p. 914-919.

Shapely, D., 1978. "Finklea Quits as Chief of Occupational Health Institute," Science, 199, p. 408, January 27.

Sheppard, W.J., 1970. "Relevance analysis in research planning," Technol Forecasting, v. 1, n. 4, Spring, pp. 371-9.

Shriner, C.R. and Peck, L.J. eds., 1978. "Inventory of Data Bases, Graphics Packages, and Models in Department of Energy Laboratories," ORNL/EIS-144, 147.

Sigma Research, Inc., 1977. "Guidelines for Estimating Present and Forecasting Future Population Distributions Surrounding Power Reactor Sites." Electric Power Research Institute Special Report, EA-427-SR, April.

Skolimowski, H., 1976. "Technology Assessment In A Sharp Social Focus," Technol Forecasting, v. 8, n. 4, pp. 421-424.

Slade, D.H. (ed.), 1968. "Meteorology and Atomic Energy, 1968," U.S. Atomic Energy Commission, Technical Information Division, TID-24190, July.

Souder, W.E., 1978. "System for using R and D project evaluation methods," Res. Manage (N.Y.); 21: No. 5, 29-37, Sep.

Starr, C., 1970. "Technology Assessment -- 1," Res Manage, v. 13, n. 6, Nov, pp. 409-24.

Starr, C., M.A. Greenfield, and D.H. Hausknecht, 1972. "A Comparison of Public Health Risks: Nuclear vs Oil-Fired Power Plants," in ERDA-69, NTIS, Springfield, VA.

Steiner, D., 1975. "Technological Requirements for Power by Fusion," Proc IEEE, v. 63, n. 11, Nov, pp. 1568-1608.

Strasser, G., 1972. "Methodology for Technology Assessment: Experiences in the United States," Seminar on Technology Assessment, organization for Economic Cooperation and Development, Paris, France, Jan.

Strasser, G., 1972. "Technology Assessment," Science Policy Reviews, Battelle Memorial Institute, Vol. 5, No. 1, pp. 7-13.

Strasser, G., 1973. "Technology Assessment — How Did We Get Hereµ Where Are We Nowµ Where Are We Headingµ," SAE Preprint 730109 for Meeting Jan 8-12 4 p.

Tanenbaum, M., 1970. "Technology Assessment -- 2," Res Manage, v. 13, n. 6, Nov, pp. 427-34.

Taylor, G.C., 1978. "Methodologies for characterizing technologies," EPRI, Palo Alto, CA, Aug, EPRI-EA-320.

Thiriet, L., 1974. "Comments on the Concept and Methodology of Technology Assessment," v. 2, no. 4, pp. 223-233.

Thurow, L.C., 1978. "Eight Imperatives for RaD," Technology Review, January.

Tolley, G.S., 1977. "Methodology of evaluating research and development projects, Final report," (COO/4128-1).

Viren, J.R., 1978. "Cross-Sectional Estimates of Mortality due to Fossil Fuel Pollutants: A Case for Spurious Association," TR-17900, Division of Policy Analysis, U.S. Department of Energy, Washington, D.C., August.

Wachtman, J.B., 1975. "Office of Technology Assessment: Overview and Materials Programs," SAE Prepar n 750727 for Meet Aug 11-14, 12 pp.

Wade, N., 1979. "CO_2 in Climate: Gloomsday Predictions Have No Fault," Science, 206, Nov. 23.

Wade-Blackman, A. Jr., 1973. "New Venture Planning: The Role of Technological Forecasting," Technolog Forecasting, v. 5, n. 1, pp. 25-49.

Warner, M. and H. Preston, 1974. "Review of Environmental Impact Assessment Methodologies." Battelle, Columbus Laboratory, EPA-600/5-74-002, U.S. Government Printing Office, Washington, D.C.

Weber, E., et al., 1971. Technology Forecast for 1980, Van Nostrand Reinhold, New York, 1971, pp. 13-50.

Wenk, E. Jr., 1975. "Technology Assessment in Public Policy: A New Instrument for Social Management of Technology," Proc IEEE, v. 63, n. 3, Mar, pp. 1371-379.

White, L.,; Ballard, C.; Hall, T.A, 1978. "Technology Assessment as an Energy Policy Tool," Policy Studies J, Autumn, v. 7, n. 1, p. 76 (8).

Young, W.C.; Sviatoslavsky, I.N., 1977. "Structural and Mechanical Design of Tokamaks," ASME Pap n. 77-WA/NE-2, for Meet Nov 27-Dec 2, 8 pp.

APPENDIX A

July, 1978

Dear Questionaire Participant;

Please attempt to answer as many of these questions as possible, even where intuition is your sole source of speculation. Your responses will be absolutely ANONYMOUS, with no attempt at labeling names, organizations or professions. Your responses will be combined statistically with those of approximately 50 other respondants. Responses to this questionaire will be very useful in directing environmental research and development decisions and projects, particularly in the area of coal-fired electric power plants. In particular, in a couple of current projects there will be attempbs at quantifying the uncertainties in levels of future standards and the implications of these uncertainties on regional and national energy planning. Your help in this is very much appreciated.

Thank you,

James Gruhl

James Gruhl
E38-408
77 Massachusetts Ave.
Cambridge, MA. 02139

1. Forces Motivating Air Pollution Standards

1-1 Do you believe that in the next 30 years there will be any relaxing of pollution standards?

opinion: o definitely o probably o unlikely o no

basis: o strong factual o moderate factual o some fact some intuition o intuitively

Comments:

1-2 If there is a relaxation do you believe it would be most likely primarily due to the force of

o economic problems
o energy system problems
o health impact information
o other ______________

1-3 Every 4 years there is a review of each of the air pollution standards; do you believe that there will be no more than 2 or 3 periods between tightenings?

o definitely o probably o unlikely o no

o strong factual o moderate factual o some fact some intuition o intuitively

1-4 Do you believe emissions standards will be rewritten from ($lbs/10^6$ Btu-in) to (lbs/kWh-out) to appropriately reflect advantages of more efficient advanced technologies?

o definitely o probably o unlikely

o strong factual o moderate factual o some fact some intuition o intuitively

1-4a All standards tend to be in round numbers, possibly avoiding the pretention of exactness. In conversions to metric do you believe this rounding will continue? _____ yes, _____ no.

(This is a difficult but important question. Please attempt it)

1-5 What do you believe the relative importances of forces motivating ambient air pollution standards are (scale each factor from 0 to 10, i.e. none to maximum force; numbers may be repeated)

___ regional political pressures for environmental quality
___ pressure on national politicians for environmental quality
___ regional political pressures for other gain (economic, employment, etc.)
___ pressure on national politicians for other gain
___ anti-'big business' or anti-establishment forces
___ EPA perception of their legal obligations to defend public health
___ EPA perception of litigation potential from impacted industries
___ time delays in legislative process
___ economic burden of new standards
___ existing community levels of pollutants
___ available pollution control capabilities
___ air pollution monitoring capabilities
___ toxicological evidence
___ toxicological speculation
___ epidemiological evidence
___ epidemiological speculation
___ correlation with other pollutants that may be harmful
___ others:

2. Air Pollution Index

2-1 Do you believe the concept of standards for combinations of more than two pollutants will be used in the next 30 years?

o definitely
o probably
o unlikely
o no

o strong factual
o moderate factual
o some fact some intuition
o intuitively

Comments:

2-2 The 1976 amendments to the Clean Air Act point to the possibility of some index. If implemented when would you guess would be the earliest and latest years?

earliest ____, likely ____, latest ____

Comments:

2-3 The index that would most likely be used would be

o no idea
o Ontario API
o AQI
o Green Combined Index
o Combustion Product Index
o Extreme Value Index
o MITRE AQI
o ORAQI
o PINDEX
o new index

Comments:

2-4 From a toxicological or epidemiological viewpoint it does not make sense to assume complete independence of pollutants; do you feel within the next 30 years a linear additive assumption will be superimposed on the threshold standards?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

3. Sulfur Pollutants

Annual average ambient SO_2 standards are currently at 80 ug/m^3, with a couple of other speculations shown

	1978	1983	1988	1993	1998
3-1 Annual SO_2					
academic speculation	80	60	60	60	50
your guess	80	___	___	___	___
3-2 24 hour SO_2					
academic speculation	365	260	260	200	200
your guess	365	___	___	___	___
3-3 3 hour SO_2					
academic speculation	none	1300	1300	1000	1000
your guess	none	___	___	___	___

3-4 List in the order you feel they are likely, any new averaging times for SO_2. (1 through 6)

__ 1 month, __ 1 week, __ 4 days, __ 8 hours, __ 1 hour, __ other

3-5 List in order the averaging times most likely to change. (1 thru 3)

__ annual, __ 24 hour, __ 3 hour

3-6 List other speculations of SO_2 standards you are aware of:

3-7 What do you feel the chances are that there will be different SO_2 averaging times?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

3-8 What do you think the most likely basis for any future point source performance standards would be?

- o all coal-fired plants must have scrubbers
- o based on dispersion to ambient standard
- o based on sulfur content in coal
- o other ____________________

3-9 Given an all-scrubber, 90% sulfur removal, coal scenario how likely is it that bypass will be allowed during scrubber outages?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

3-10 Given the all-scrubber coal scenario with bypass what is the likely duration limit on bypass?

- o 8hr/month
- o 1 day/ month
- o 3 days/ month
- o 1 week/ month
- o other __________

3-11 ...and what kind of sulfur content do you believe will have to be in the special coal burned during bypass ?

- o .7% sulfur
- o 1.5% sulfur
- o 2.2% sulfur
- o any available

3-12 Do you feel the public perceives the SO_2 question to be currently controlled

- o too much
- o very well
- o too little
- o don't care
- o other _______

3-13 What is your speculation on SO_x emissions limits for coal plants?

	1978	1983*	1988	1993	1998
academic speculation	1.2lb/10^6Btu	.2	.2	.2	.2
regulatory speculation	1.2	.5	.5	.5	.5
regulatory speculation	1.2	1.2 max. + 80% removal			
regulatory speculation	1.2	1.2 max. + 90% removal			
utility speculation	1.2	1.2	.6	.3	.3
your guess	1.2	____	____	____	____

* 1983 has been chosen due to EPA suggestions that this is the target date for Revised New Source Performance Standards.

3-14 Do you feel that politics of eastern versus western coal-use will dominate sulfur regulations?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

Comments:

3-15 Do you feel there is an epidemiological or toxicological basis for your speculations of different SO_2 standards?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

Comments:

3-16 Is the scrubber industry sufficiently developed to provide the quality and reliability of scrubbers that might be needed?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

Comments:

3-17 What other environmental gains are there from scrubbers?

3-18 Do you believe an all-scrubber coal scenario would be possible without regenerable processes?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

Comments:

3-19 Where do you think the annual average sulfate standards would be set. Current levels range up to 16 ug/m^3, health impact speculations begin also at that level.

	1978	1983	1988	1993	1998
speculation	none	none	25	20	20
your guess	___	___	___	___	___

3-20 Do you believe that health impacts now being attributed to sulfates will move over into nitrates?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

3-21 Do you have any feelings about how the long-range, 100 to 500 mile, nature of sulfates can be regulated in a point source emission context?

Comment:

3-22 List in order of likelihood the most likely additional averaging times for sulfate standards.

___ 1 month, ___ 1 week, ___ 4 days, ___ 1 day

3-23 How likely do you believe it is that there would be, within 30 years, sulfuric acid aerosol pollution alerts, e.g. during 0.5-micron-fog inversions

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

3-24 How likely is it that acid rain problems will ever unravel back to sulfur emission regulations?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

3-25 Do you think it is politically feasible for the federal EPA to set very different sulfur emission standards for different regions; e.g., New England and Midwest.

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

3-26 There is some use of an SO_2 times particulate ambient 24 hour standard of 4.9×10^5 $ugm^2{}^2/m^6$. When and how much do you believe a federal standard would be? _______year, _________ level

3-27 Do you believe there is a more accurate representation of any such synergistic effect? What?

3-28 With sulfur removal in a year-2005 MHD plant projected at 99.6% removal do you believe the sulfur issue will die?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

4 Particulates

Please offer your speculations on the following particulate ambient standards.

	1978	1983	1988	1993	1998
4-1 Annual TSP					
academic speculation	75	60	60	60	60
your guess	75	___	___	___	___
4-2 24 hour TSP					
academic speculation	260	150	150	150	150
your guess	260	___	___	___	___

	1978	1983	1988	1993	1998
4-3 Annual fine part. (less than 3 microrons)					
academic speculation	none	20	20	20	20
your guess	none	___	___	___	___
4-4 24 hour fine part.					
academic speculation	none	50	50	50	50
your guess	none	___	___	___	___
4-5 8 hour fine part.					
academic speculation	none	none	125	125	125
your guess	none	___	___	___	___

4-6 Do you believe there is another averaging time that will become important in the next 30 years? What?

4-7 Do you feel visibility standards will within the next 30 years have impact on particulate emissions limits?

o definitely
o probably
o unlikely
o no

o strong factual
o moderate factual
o some fact some intuition
o intuitively

4-8 Do you think there will be respirable particulate/asbestos synergism standards? ___ yes, ___ no. If yes, ___ higher or ___ lower than 1.5 x 10^6 fiber ugm/m^3 24 hour?

4-9 By when if they do come? ______

4-10 In what form are they most likely?

What do you speculate the particulate emission limits for coal plants will be?

in $lb/10^6$ Btu

	1978	1983	1988	1993	1998
4-11 Total particulates					
academic speculation	0.10	.03	.02	.02	.02
utility speculation	0.10	.02	.02	.02	.02
your guess	0.10	___	___	___	___
4-12 Fine particulates					
utility speculation	none	.02	.02	.02	.02
your guess	none	___	___	___	___

4-13 The very fine particulates in the 0.1 to 0.3 micron range are currently without any control technology. Do you believe this range will receive any attention in the next 30 years?

5. CO_2

5-1 Do you feel that the global heat balance issue will in the next 30 years affect combustion emission standards
Comments:

- o definitely
- o probably
- o unlikely
- o not

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

5-2 If strong evidence arises for both(1) a new Ice Age and (2) fossil combustion pushing off its start, then there would be fossil combustion legislation to affect
Comments:

- o electric capacity planning
- o planning and operation
- o operation
- o none

5-3 Do you believe the discovery of such evidence over the next 30 years is

- o definite
- o probable
- o unlikely
- o not coming

6. CO

6-1 Do you believe that carbon monoxide emission standards will ever be any kind of a limitation for power plants?

- o definitely
- o probably
- o unlikely
- o no

Comments:

6-2 The current carbon monoxide 8 hour ambient standard is 10000$\mu g/m^3$. Do you believe, in the future, this will be
Comments:

- o substantially lowered
- o lowered
- o constant
- o relaxed

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

6-3 The current carbon monoxide 1 hour ambient standard is 40000 $\mu g/m^3$. Do you believe in the future this will be

- o substantially lowered
- o lowered
- o constant
- o relaxed

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

6-4 Do you believe that carboxy-hemoglobin concentrations at or below levels that impair athletic performance will in the next 30 years be linked to irreversible nervous, respiratory or circulatory system changes?
Comment on level:

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

6-5 Do you know of any technique for controlling CO other than choice of combustion type or tuning of combustion efficiency?
_____ don't know of any; yes - ______________________________

6-6 Do you know of any recentCO standards speculations?

7. Oxidants

Please offer your speculations on the following ug/m^3 oxidant standards.

	1978	1983	1988	1993	1998
7-1 Ambient 1 hour					
academic speculation	160	160	160	160	160
your guess	160	___	___	___	___
7-2 Ambient 8 hour					
academic speculation	none	none	none	100	100
your guess	none	___	___	___	___

7-3 Do you think community levels of oxidants will be correlated with anything other than nuisance effects?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

7-4 Other than using NO_x and hydrocarbon controls do you know of any point source controls that would affect ambient oxidant levels? What?

7-5 Do you believe within 30 years oxidants will be correlated with mutagenic effects?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

8. Nitrogen Oxides

What is your speculation on the NO_2 ambient level standards?

	1978	1983	1988	1993	1998
8-1 Annual NO_2					
academic speculation	100ug/m^3	100	50	50	50
your guess	100	___	___	___	___
8-2 24 hour NO_2					
academic speculation	none	400	400	400	400
your guess	none	___	___	___	___
8-3 1 hour NO_2					
academic speculation	none	none	1000	1000	1000
your guess	none	___	___	___	___

8-4 Emissions from coal-fired plants (in lb/ 10^6 Btu)

	1978	1983	1988	1993	1998
academic speculation	0.7	.6	.6	.6	.6
utility speculation	0.7	.4	.15	.15	.15
utility speculation	0.7	.28	.14	.14	.14
research speculation	0.7	.21	.21	.21	.21
your guess	0.7	___	___	___	___

8-5 Supposing the inevitability of an NO_3 ambient standard, what is your guess at year of introduction?

earliest _____, likely _____, latest _____

8-6 Do you believe the NO_3 level would be set on the basis of

- o slightly tightening ambient levels
- o significant tightening ambient levels
- o health impact information
- o other ______________________

8-7 Since NO_2 in moderately high amounts actually screens out solar radiation necessary in smog formation, do you believe NO_2 levels will ever be allowed to rise as a control measure?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

8-8 Do you believe that NO_x scrubbing will ever be the issue SO_x scrubbing has been?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

8-9 Do you feel that NO_x will be sufficiently correlated with mutations to cause controls on that account within the next 30 years?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

8-10 If there is an NO_x — mutation connection, do you believe it will be assumed linear at very low levels?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

8-11 Please rate from 0 to 10 how strongly you feel public pressure for NO_x controls would be due to

____ reduction in visibility and browning of air at horizon
____ eye irritation
____ slightly increased mutations
____ slightly increased cancer rates
____ additional nervous disorders and temperament problems

8-12 Do you believe there will be an NO_x times hydrocarbon threshold ____ yes, ____ no

9. Hydrocarbon Emissions

9-1 Do you believe the current 3 hour ambient hydrocarbon level of 160 ug/m^3 will be tightened? ____ yes, ____ no.

9-2 If tightened, by what year? _____ earliest, ____ most likely, _____ latest.

9-3 To what level? ________

9-4 There are inert hydrocarbon emissions and also very toxic emissions. Do you believe EPA will tackle the huge monitoring problems and within the next 30 years split up its total hydrocarbon category to reflect this?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

9-5 Given more than one category, do you believe that the categories will go by cancer inducing activities? ____ yes, ____ no.

9-6 Given carcinogenic categories such as -, +, ++, +++, and ++++, do you believe five categories is too many? ____ yes, ____ no.

Circle the most likely number: 2 3 4 5 6 7

9-7 Where do you believe the most binding hydrocarbon constraint for new coal power plants will come?
- o licensing
- o operating emissions
- o ambient constraints
- o other ________

9-8 Given some polyclclic organic material (POM) hazardous emission limitation what do you believe will be the year it will be implemented? _____ earliest, _____ most likely, _____ latest

9-9 How likely is it that there will be a connection beyond reasonable doubt of organic sulfur or nitrogen compounds to human cancer?
- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

9-10 Do you believe that such a connection could within the next 30 years reflect back on sulfur or nitrogen emission thresholds
- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

9-11 How likely is it that a carcinogenic cost/benefit analysis would be a licensing requirement for new coal power plants inthe next 30 years?
- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

9-12 Given such a cost/ benefit requirement what year is: _____ earliest, _____ most likely, _____ latest.

9-13 Do you believe such an analysis would ever be required of existing plants for retrofit considerations?
Comments:
- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderatd factual
- o some fact some intuition
- o intuitively

9-14 Do you feel that such an analysis could be the only control placed on carcinogenic emissions from coal-fired facilities?
- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

9-15 Given such an assessment what level do you feel the whole procedure would balance-off at: 1000 MW equals ____ excess annual cancers per million people. (1000 MW serves about one million people.)
Comments:

9-16 Do you believe that such a raw comparison will ever be made (as opposed to being implicit in an obscured procedure and thresholds).
- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

10. Trace Elements

10-1 There are a number of trace elements that have been identified as suspected carcinogenic materials. Do you believe these will receive separate treatment (as opposed to some combined index).

o definitely
o probably
o unlikely
o no

o strong factual
o moderate factual
o some fact some intuition
o intuitively

10-2 Given a combined index strategy can you think of a likely way other than carcinogenic cost/benefit analysis?

What?

10-3 Currently, averaging times for recommended levels of trace elements range from 1 day to 1 year. If all are monitored over the same period, label the "most-likely" to "least-likely" periods, 1 through 5.

____ 24 hours, ____ 3 days, ____ 1 week, ____ 1 month, ____ 1 year

Given everything scaled to a 24 hour period, can you speculate on likely levels for:

(all in ug/m^3)

		1978	1983	1988	1993	1998
10-4	24 hr arsenic					
	academic speculation	none	none	.15	.10	.10
	your guess	none	____	____	____	____
10-5	24 hr beryllium					
	academic speculation	none	.02	.02	.02	.02
	your guess	none	____	____	____	____
10-6	24 hr cadmium					
	academic speculation	none	none	.05	.05	.05
	your guess	none	____	____	____	____
10-7	24 hr mercury					
	academic speculation	none	.10	.10	.10	.10
	medical speculation	none	.30	.30	.30	.30
	your guess	none	____	____	____	____
10-8	24 hr nickel					
	academic speculation	none	none	.03	.03	.02
	your guess	none	____	____	____	____
10-9	24 hr vanadium					
	academic speculation	none	none	none	none	none
	your guess	none	____	____	____	____

	1978	1983	1988	1993	1998
				(all in ug/m^3)	
10-10 24 hr lead					
academic speculation	none	none	1.5	1.5	1.2
your guess	none	____	____	____	____
10-11 24 hr asbestos fibers (in fibers/m^3)					
academic speculation	none	1000	1000	1000	800
your guess	none	____	____	____	____

10-12 It is known that for all of these trace elements there are inert compounds as well as suspected potent compounds. Do you feel within 30 years there will be enough monitoring and health impact information to regulate trace elements by specific compounds.

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

10-13 Do you believe the 80% target removals of chlorine planned by EPA will be promulgated?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

10-14 Please rate from 0 to 10 your speculation of the likelihood of regulation of the following trace elements:

___ asbestos	___ cadmium	___ lead	___ selenium
___ arsenic	___ chlorine	___ manganese	___ tellurium
___ barium	___ cobalt	___ mercury	___ thallium
___ beryllium	___ copper	___ nickel	___ vanadium
___ boron	___ flourine	___ phosphorous	___ zinc

11. Radiation

11-1 Do you believe "lowest practicable" radiation standards for nuclear facilities are a 'dead horse' as far as political mileage is concerned?

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

11-2 Do you believe the "lowest practicable" limit on radiation will ever be imposed on radium and other coal plant emissions

- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

11-3 Some coal is as high as 3% uranium; do you feel uranium content limits will be imposed on coal? ____ yes, ____ no.

11-4 By what year? _____ earliest, _____ most likely, _____ latest.

11-5 If such a limit is set, do you believe it will be primarily motivated by
- o east vs. west politics
- o projected ambient radiation levels
- o slightly restricted choice of coals
- o significantly restricted choice of coals
- o other ______________________

11-6 Do you believe that within the next 30 years the carcinogenic cost/benefit numbers from coal plant studies will be used to relax nuclear plant controls?
- o definitely
- o probably
- o unlikely
- o no

- o strong factual
- o moderate factual
- o some fact some intuition
- o intuitively

11-7 A recommended ambient level of .02 Curies/year has been suggested. If implemented, what year do you believe it would be introduced?

_____ earliest, _____ most likely, _____ latest

12. Occupational Health Questions

12-1 The number of criteria documents in which NIOSH has outlined occupational health hazards has recently increased sharply from 23 to 88 total criteria documents. Do you feel this trend will
- o accelerate
- o continue
- o moderate
- o drop sharply

12-2 Do you feel the implications of these occupational criteria on the introduction rate of public health criteria will be
- o quite great
- o moderately strong
- o moderately weak
- o very weak

- o strong factual
- o moderate factua
- o some fact some intuition
- o intuitively

Comments:

12-3 Rate as 0 through 10 by importance the factors that you believe have or will most affect the regulation of air pollutants in the workplace:

___ a new assistant secretary of OSHA, Eula Bingham, appears "determined to make up for years of inactivity under Republicans" (Shapley, 1978) in restricting air pollution in the workplace.
___ pressure from labor representatives
___ better dose/response health effects techniques and information
___ general public insistence or attitudes
___ anti- management or anti-establishment forces
___ economic and employment climates
___ other ______________________