

A Summary and Report on Four National Environmental Workshops

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July 1980

U.S. Department of Energy
Assistant Secretary for Environment
Office of Environmental Assessments



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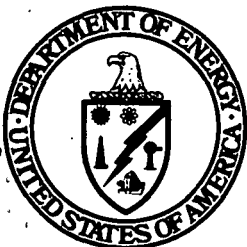
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A Summary and Report on
Four National Environmental Workshops

July 1980

U.S. DEPARTMENT OF ENERGY
Office of Environmental Assessments
Assistant Secretary for Environment

Index

Executive Summary.....	1
Defining the Problems.....	3
The Workshop Vehicle.....	5
Workshop Overview.....	6
Conclusion: Insights for Policy Analysis.....	9
Some New Insights?.....	11

Appendices:

Appendix A: Proceedings of a Workshop on
Integrated Assessment for
Energy Related Environmental
Standards -- Berkeley,
California, November 2-3, 1978.

A-1

Appendix B: Proceedings of a Workshop on
National Ecological Assessment --
Savannah, Georgia, January 10-12,
1979.

B-1

Appendix C: Proceedings of a Workshop on
National/Regional Energy -
Environmental Modelling Concepts --
Reston, Virginia, May 30 -
June 1, 1979.

C-1

Appendix D: Proceedings of a Workshop on
Ground Water and Energy --
Albuquerque, New Mexico,
January 29-31, 1980.

D-1

EXECUTIVE SUMMARY

The Office of Environmental Assessments within the Department of Energy conducts an integrated assessment program within the energy/environmental policy area. During the implementation of this program, many questions have repeatedly demonstrated themselves as issues which affect the ability to perform conclusive assessments. Here are some examples:

- o Is it possible to perform integrated assessments for energy related environmental standards?
- o Is it possible to have consistent applications of national and regional environmental energy modelling concepts to integrate them effectively and efficiently?
- o Is it possible to perform and integrate non-site-specific ecological assessments within the environmental analysis area?
- o Can groundwater provide sufficient supply for energy development in areas where surface water is in short supply?

In order to examine these specific questions and drive toward both their understanding and resolution, four workshops were held during the last two years: (1) Integrated Assessment for Energy Related Environmental Standards Workshop - Berkeley, California, November 1978; (2) National Ecological Assessment Workshop - Savannah, Georgia, January 1979; (3) National/Regional Modelling Workshop - Reston, Virginia, May 1979; (4) Groundwater Workshop - Albuquerque, New Mexico, January 1980.

The results of these workshops were as varied as the questions themselves. At the workshop on integrated assessment for energy related environmental standards, the participants concluded that such assessment, as currently practiced, is an art, however scientific in concept; that opinions and expertise of both technicians and decisionmakers will determine the manner in which it is performed. The successful implementation of integrated assessment within the Federal Government depends, they agreed, upon realizing that it represents a fairly fundamental change in the reward structure of policy and planning within the government which would require a major shift in attitude.

Both national and regional modelling approaches are necessary for environmental assessments. The models currently used should be improved and a core set of related models should be developed that are modular, dynamic and consistent; that have an inter-industry accounting framework, interregional linkages, adequate documentation and an appropriate methodological framework. Five major themes emerged in this area and are presented within this paper. The big problem was the inability of the participants to recognize or address such questions as: why had not such a family of models been built; if built, where such models would reside; finally, what would they be used for?

Key ecological processes were identified at the National Ecological Assessment Workshop. These processes were productivity, cycling of elements and succession. In dealing with these processes, the important issues are long and short term changes in productivity, changes in energy flow, changes in soil fertility, effects on adaptability and resiliency of systems and changes in the rates of timing of biological phenomena. Most estimates of impacts or changes in land use or hydrologic regimes, or by releasing harmful residuals to the air or water, have to be qualitative at this time. Estimation of impacts at larger scales, the participants agreed, is particularly difficult at this time.

The Groundwater Workshop concluded that general groundwater supplies are adequate for energy needs nationally, but local shortages exist. Data bases and modelling tools are generally well developed at the regional level, but data are often deficient at the local level. Use of groundwater for energy production entails the possibility of environmental degradation; additional information must be collected regarding prevention. Saline groundwater, deep groundwater and dewatering of mines offer alternative

sources of supply, but have associated problems. Finally, the Department of Energy needs to more explicitly define and publicize its policies and activities that affect water.

The National Ecological Assessment Workshop, as it progressed, demonstrated that the questions under discussion were somewhat alien to the way these scientists had been trained to do research. There was evident discomfort at their providing information which was relatively "inaccurate" in that it had not been exhaustively studied in a carefully controlled (i.e., scientific) situation or which was not site-specific in nature. "Average" coefficients, even for screening purposes, were suspect; science did not prepare the participants for such analyses.

We hope that these insights and those contained in the short accompanying paper will provoke serious thought among our colleagues. We believe that such consideration is the principal basis for policy analysis and is therefore appropriate for such serious inspection and much further discussion.

For the convenience of our readers, we have pulled together in this document the individual reports and proceedings from the four workshops, two of which had been previously printed and made available to a limited audience.

Peter W. House
Director
Office of Environmental Assessments

DEFINING THE PROBLEMS

The Office of Environmental Assessments implements a unique program within the Department of Energy. Its principal responsibilities are to establish plans for, and to assess the related environmental implications of the development and deployment of new energy technologies; to conduct regionally oriented ecological and environmental analyses which are designed to establish the sensitivities of these areas to existing and planned implementation of energy technologies and programs; to perform integrated policy analyses which bring together energy technology, environmental and economic considerations designed to influence the Federal energy program. It is not surprising that this organization should experience problems which other practitioners of the art and science of policy analysis have been grappling with for some time. For the past several years, this organization has confronted these recurring problems: how to perform integrated assessments for energy related environmental standards; questions concerning the application of national and regional environmental/energy modelling concepts and their effective and efficient integration; the inability to perform and integrate non-site-specific ecological assessments within the environmental analysis area; the question of whether groundwater can provide sufficient supply for energy development in areas where surface water is in short supply.

Integrated Assessment for Energy-Related Environmental Standards

The first of these problems is a general question which concerns itself with the process of applied analysis. It is a fundamental question which points to the relevancy and effectiveness of analysis as a decisionmaking tool. The question is therefore especially meaningful from the perspective of the Office of Environmental Assessments.

Emerging as a central problem of contemporary environmental policy analysis is the inability to systematically and objectively determine whether any given trade-off leaves us better or worse off in the aggregate. An integrated assessment attempts to present the full range of consequences of a given policy action, all the costs and benefits whether economic or environmental, intended or unintended, prompt or delayed, in order to determine whether the action will make society better or worse in the aggregate. Integrated assessment also means taking all such tradeoffs into account in determining whether or not the policy in question is advantageous. We are immediately faced with a number of difficult questions: How great are the intrinsic handicaps imposed by the state-of-the-art in environmental science and environmental economics on the policy community confronting this integrated-assessment task? What are the prospects for reducing these handicaps in time? How might the formation of environmental policy best proceed given those elements of the problem which will not soon be reduced?

National/Regional Energy-Environment Modelling Concepts

A particular problem experienced by the Department of Energy concerns which modelling approaches to regional economic and energy forecasting are best suited in assisting the Department in the assessment of environmental impacts of energy policies. These models are used to assess the impacts of technology change, to analyze differential impacts of various energy policies and to provide an early warning system of possible constraints. Currently, the Department uses both a "top-down" modelling system to analyze national scenarios and a "bottom-up" assessment conducted from a regional perspective. A principal question is how the Department can "couple" or link these models or their results. The ability to do so might make it possible to standardize related assessments within a consistent framework, regardless of whether such assessments are initiated at the macro or micro level.

Non-Site-Specific Ecological Energy Technology Assessment

Ecological assessment is an area which may be the most difficult to assess and incorporate within environmental assessments. Analytical methods for assessing the environmental impacts of a potential source of insult upon air, water and land are both well-defined, objective and highly quantitative. In contrast, ecological assessments are site specific with the method of assessment, and the determination of environmental impact and the incorporation of assessment results both highly judgmental and qualitative. These characteristics result in ecological assessments being resource intensive, raising serious questions concerning their value and how assessment conclusions can be incorporated into the decisionmaking framework.

The key question is how to develop an analytical framework for performing non-site-specific ecological assessments of energy development impacts. Environmental assessments are often complicated by the varying spatial and temporal scales used. Energy policy decisions are frequently based on alternative energy scenarios that project technology mixes and energy development 20 or 30 years in the future. But projected energy or industrial facilities are seldom sited in more detail than at the county level, thus reducing the accuracy of the impact analysis. The reliability of many analyses (e.g., ecological, socioeconomic or water quality) decreases as the spatial and temporal scales broaden.

A good deal of effort has been directed toward identifying and quantifying the environmental impacts of energy-related activities. Quantification of impacts, of course, depends on developing a sound data base. In many cases, such quantification has been achieved for specific kinds of impacts, but not, however, for the evaluation of the ecological impacts of general energy activities. Consideration of ecological impacts has been hampered to date by the complexity of natural systems and the lack of adequate data bases on direct-dose-response effects and on multidimensional effects such as predator/competitor responses.

Groundwater and Energy Production

The question concerning groundwater focuses on whether a sufficient supply of groundwater exists to allow energy development in areas where surface water is in short supply. Peripheral questions concern the quality and quantity of the nation's groundwater stock. What are the barriers to use of groundwater resources for energy? What technical and institutional options are available for obtaining groundwater for energy facilities? This concern is especially relevant to the ability of this nation to produce synthetic fuels, since much of the synfuels production is targeted for the West, where water quantity and quality are critical concerns.

THE WORKSHOP VEHICLE

Several methods might be used to carry out a research program or project in any specific subject. Regardless of which of these methods is chosen, there will be a need, sometime in the design, to determine what is known about the subject area and where one stands in relation to this knowledge base. These exercises usually go under the guise of surveys of the literature and state-of-the-art reviews. They can be carried out in several ways: through literature searches, by questionnaire, by interview or by workshops. In any case, they are an important and unique part of any research or analysis function.

The Office of Environmental Assessments in 1978 designed a series of workshops to focus the attention of some of the nation's leading technology and policy analysts on these problems and some possible solutions. In the past, the Department had used workshops to help define a problem and either to substantiate that definition or provide accurate redefinition. In a workshop setting, there can be detailed examination of the problem and the sharing of information which in turn can lead to greater insight into a given problem. Rarely is there a synergistic leap forward to the resolution of the problem. Clearly then, although not expecting problem resolution, workshops, if properly structured, can yield beneficial results.

The Office of Environmental Assessments developed and implemented several guidelines for this exercise:

- o The workshops should rapidly inform the Department's environmental assessment staff of the state of knowledge concerning the particular topics and provide expert advice on problem resolution approaches.
- o The workshops should be short (2-3 days) and relatively small (less than 20 non-Federal participants).
- o Participation in the workshop should be by invitation only.
- o The work agenda for the workshops would be carefully planned and managed in order to stick to the main issues.
- o Consensus ideas would be developed and documented whenever possible.
- o Formal proceedings of the workshops would be well documented and published.

WORKSHOP OVERVIEW

The workshops summarized below were designed to provide a consensus of what the current problem resolution capabilities are in these areas of concern to the Department of Energy and to provide direction for future research. The specific workshops were designed to gather together experts from diverse disciplines related to the subject area to address a specific and hard-to-handle question in a give-and-take discussion, steering clear of bureaucratic staff papers and policy lectures. Each workshop was convened to address a question of concern in the area of energy and environmental analysis. The subjects chosen, as indicated above, were issues seldom handled explicitly in public policy analyses. The workshops were held to determine why and to suggest how present practice could be improved.

The four workshops were well attended and the participants generally entered into the problem solving mode of the sessions with good intentions and high spirits. The proceedings of each workshop can be found in the appendices to this report, as well as lists of the participants. The results of the workshops were, for a variety of reasons, not as useful as had been hoped. The quality of the workshops varied considerably, but none contained the beginnings of innovative solutions hoped for. This is not to say that the results were not useful. Each workshop resulted in a clear addition to their general knowledge base. In each case, the participants recognized that there are not clear-cut solutions to the problems explored within the workshops. In every case, gains were made. The problem areas addressed were more clearly delineated than previously, arguments associated with the problems were updated and verified, and the need for new approaches presented in a clearer fashion.

1. Integrated Assessment for Energy-Related Environmental Standards Workshop - Berkeley, California; November 1978

The conclusion of this workshop was that no Federal agency practices integrated assessment, either broadly or consistently, not even in the narrow technical sense of assuring that all factors that might impact an energy technology are considered. When integrated assessment is widened to include the political pressures and time constraints of the top-level administrators and decisionmakers, the improbability of its being carried out successfully increases substantially, even though administrators do try to consider a wide range of impacts. Personal and professional opinions differ widely on the extent to which attempts should be made to interrelate these impacts, to bring about synergistic, genuinely integrative effects. Integrated assessment, as currently practiced, is an art, however scientific its concept may be. Opinions and expertise of both technicians and decisionmakers will determine how it is performed. Integrated assessments will not replace the decisionmaker, but it might make the decisionmaker's position easier and more secure.

What constitutes integrated assessment for various agencies at various times differs in both theory and practice. The mission of each agency determines what impacts must be taken into consideration, or at least which should be given priority. It becomes obvious that each agency must construct its own framework for integrated assessment.

How can a process like integrated assessment be institutionalized so as to progress beyond the usual bureaucratic assessment procedures? The secret of integrated assessment is realizing that it represents a fairly fundamental change in the reward structure of Federal agencies. Good managers are presently defined as, inter alia, technically competent. Integrated assessment appears to overtax their competence to make broad judgments required of them. To change the reward structure of policy and planning within agencies requires a shift in attitude. Most people would agree to a reasonable, clearly defined, objective function if the shift were recognized by their superiors, the decisionmakers, and if, in the final analysis, it were properly used.

2. National/Regional Modelling Workshop - Reston, Virginia; May 1979

The workshop participants agreed that there was a need for both top-down and bottom-up modelling approaches, so that various levels of interactions in energy-economic-environmental modelling systems could be adequately represented. For the short-term, the currently used models should be improved, and specific recommendations were made about how that could be done. Most of the comments, however, were directed toward the development of a new methodology. A core set of related models should be developed that are modular, dynamic, and consistent; that have an inter-industry accounting framework; that have inter-regional linkages; that have adequate documentation; and that have an appropriate methodological framework.

To improve the quality of the data used in any policy analysis model, the participants recommended that the Department develop and maintain an integrated system of economic, environmental, and energy accounts coordinated with the statistical agencies that collect the data. An independent group should be established to oversee energy data collection, coordination, and verification. The Office of Environmental Assessments should play a major role in ensuring that the data it needs for policy analysis models are collected and compiled in a suitable way.

States and regions should be more involved in the assessment process, with the state as the basic geographic unit and states being encouraged to participate in the siting and disaggregation processes, as well as in the interpretation and evaluation of the impacts.

To improve the design of assessment programs, the participants recommended improvements in energy and economic scenarios, better data on the cost of environmental standards, and more thought on the appropriate time frame for conducting a given policy analysis. They emphasized that a closer relationship should be established between the decisionmaker, the model and the modeller, in order to guard against misuse of the model results.

Five major themes emerged from the individual working group recommendations. First, the top-down and bottom-up approaches to policy analysis are compatible and can be used in an integrated fashion. Second, the methodology suggested for the integration processes should consist of a core set of linked basic models with the other special purpose models for specific assessments. Third, the data and models used in this methodology require review, verification, and validation by outside groups. Fourth, regional and state involvement is necessary in any Federal assessment process to enhance credibility and to increase accuracy. Finally, there is a need for a close relationship and communication between the decisionmaker, the model and the modeller in order to maximize the proper use of the output.

3. National Ecological Assessment Workshop - Savannah, Georgia; January 1979

The workshop participants identified three key ecological processes: productivity, cycling of elements, and succession. In dealing with these processes there are several key issues: long and short term changes in productivity, changes in energy flow, changes in soil fertility, effects on adaptability and resiliency of systems, and changes in the rates of timing of biological phenomena. Most assessments of impacts on changes in land use or hydrologic regimes, or by releasing harmful residuals to the air or water, have to be qualitative at this time. Estimates of impacts at larger scales is particularly difficult.

Five kinds of species should be considered in an assessment of impact on populations: rare, endangered, keystone (species that play a critical role in the ecosystem), dominant and indicator. For each kind of species, the important issues relate to habitats, stability and homeostasis, population, survival level, changes leading to secondary effects, distribution and range, reversibility of impact. For future non-site-specific assessments, collection and assimilation of distributional data is needed, including improved local studies and biological information. For assessments of populations at different spatial scales, a major concern is data reliability.

Two major concerns relative to ecosystems are the resource and species interactions within and among ecosystems and ecosystem patches, and the "normal" pattern of perturbations or stresses that maintain the ecosystem. The participants discussed several important characteristics of all systems as they relate to these major concerns: regulation of structure, composition, and function; frequency of perturbation; regulation of biochemical cycling; ecosystem interactions; ecosystem resiliency and health; patch-mosaic properties. Methodology suggestions include use of a three-dimensional "conflict matrix" with different energy technologies on one axis, ecoregions on another, and ecosystem types on the third; identifying the limiting factors in energy/material flows within a system; and tracing the total flow of materials throughout the system. The participants recommended that models for terrestrial systems similar to those already developed for aquatic systems be developed. Basic research on ecosystem geochemical responses should also be expanded. Data bases should be developed that show landscape patterns for a broader area, as well as methods developed for describing existing patch dynamics at the county level. As many instances as possible of human alterations of perturbation cycles should be documented.

4. Groundwater and Energy Workshop - Albuquerque, New Mexico; January 1980

The workshop conclusions were the nation's supply of groundwater comprises some 200 billion acre feet within four thousand feet of land surface. Additional large quantities of unexploited brackish, saline, and "deep" groundwater can be developed. The legal systems for allocating ground and surface water are generally not consistent with the physical interrelationships that exist between water on and below the surface. Quantity and quality aspects of water resource management are approached as independent elements when in reality they are interrelated components of water resources. Administration of the two elements by different agencies makes for inefficiency and conflicts. Aquifers bisect political boundaries with different policies and legal structures. The many actors and activities may frustrate development of water by energy facilities.

Federal policy and Federally assisted programs may intensify the pressure to use the groundwater resource, but control of groundwater management remains with the individual states. Conflicts may develop between uses of aquifers for water supply and energy related activities which may degrade those aquifers by the introduction of extraneous materials. Heavy withdrawals from aquifers by energy facilities will certainly cause conflicts.

CONCLUSION: INSIGHTS FOR POLICY ANALYSIS

One might reasonably ask what benefit was gained from these workshops and should similar exercises be held in the future. Overall, the experience was disappointing; the results tended to add little to what was already known about the individual workshop themes. Because the amount of effort and organization in setting up the workshops was adequate and because the participants were generally highly qualified and motivated, we have concluded that the questions themselves might have been too fundamental and too difficult to be addressed in this fashion. This somewhat disappointing result does not, in any way, suggest that the workshops should not have been held. The individual workshops tended to sharpen the definition of the problem areas in a useful fashion. Further, it became clear that no simple or short-run solutions existed to the issues posed by the workshop conferees. These, in and of themselves, are useful conclusions and can help to focus future research. Further, some ancillary research insights were gained for those interested in improving the art of public policy analysis, although these insights were not part of the original design of the workshop organizers.

Looking at each workshop once again, we can suggest at least one result for observers and participants which was not intended.

- o The Integrated Assessment for Energy-Related Environmental Standards Workshop, as earlier noted, was designed, among other things, to investigate the benefits, techniques, and feasibility of looking at environmental impacts in a comprehensive, integrated fashion. As one of the inputs to the discussion, working papers were prepared which reviewed the development of environmental standards and policy in areas ranging from air, to water, to strip mining.

The people preparing the papers used secondary sources and had the papers reviewed before presentation. As a part of the workshop design, people were invited who were active (in a policy sense) in the development of all or a portion of the standards or policies addressed in the papers. These practitioners disagreed not only with ascribed motivation, but even with actual events described in the papers. It appears that actual participants in real events question descriptions of those same events when they are derived from secondary sources.

It might be interesting to research the question of whether these generalizations are valid in areas other than environmental assessment. For the moment, let us merely note that much of the development and refinement of the techniques used in the analysis of policy issues is performed by academic researchers who usually must rely on secondary sources for their information. If the understanding they have of the policy milieu comes from incomplete or inaccurate descriptions, how can the techniques they develop and refine be useful to policy analyses? The scientific method requires continual observation and reporting of phenomena and the development of theories from such observations. If the observations are flawed or skewed, their theory is sure to be. The models and techniques built from these theories are bound to also be inaccurate. The resulting predictions, based on flawed theory and using flawed techniques, will not properly reflect reality.

- o The primary issue addressed by the National Ecological Assessment Workshop was how to perform non-site-specific assessments which could be used for technology analyses of broad energy and environmental policies. It was attended by several highly qualified ecologists who spent most of the time at the workshops cataloging the issues and building taxonomies for broader-based assessments. It became clear, as the workshop progressed, that the questions posed by the workshop were somewhat alien to the way these scientists had been trained to think. There was discomfort evident at their providing information which was relatively "inaccurate", in that it had not been exhaustively studied in a carefully controlled situation (was not "scientific") or was not site-specific in nature. "Average" coefficients, even for screening purposes, were suspect.

Further, there really were no methods or data bases available to carry out such assessments, although some beginnings could be made. In short, it was clear that nobody present at the workshop appeared to have really thought extensively of questions in this top-down fashion before and their backgrounds did not really prepare them for such analyses. Certainly, such assessments are needed to carry out public policy analyses. Although the ecologist has provided yeomen service to the environmental community in his inputs to environmental impact statements, his contribution to such wide-reaching issues as acid rain may be less useful because it is more anecdotal.

- o The National-Regional Energy-Environmental Modelling Concepts Workshop set out to look at the computing perceptions of top-down and bottom-up modelling with an eye toward melding the techniques. The workshop had invited participants from both camps, who discussed their experiences with their pet techniques. The working sessions then went on to look at questions of cost, feasibility, and other such matters.

In general, the workshop concluded that one method was not better than another and that clearly both were needed. This was to be accomplished by creating a family of linked models. What was more interesting, however, was the failure to recognize or address such questions as: why had not such a family of models been built already? If built, where would they be housed? What would they be used for? A whole host of such practical questions can be raised concerning the issues surrounding implementation and use.

SOME NEW INSIGHTS?

No new, neat, symmetrical or comprehensive conclusion can be drawn from these workshops. The findings we have noted were secondary and not really a part of the purpose of the workshops as planned. Had such been our purpose, a workshop series might have been designed with this in mind and a series of testable hypotheses presented. Further, none of the findings, even of these individual studies, can be spoken of as anything but suggestive, because the study was not designed to test the propositions drawn above. Even so, these partial and fortuitous findings are interesting.

The Integrated Assessment conference suggests that there are serious grounds for questioning the whole basis on which our policy analysis tools are constructed: to the extent that secondary sources are the bases for hypothesis building about how the public sector works, they are very likely to be incorrect. One conference suggested that when technicians get together they can agree on what really should be done to put together a first-rate analytic capability, but fail adequately to address questions of how to go from concepts to reality. If it is easy, why are such ideal schemes not in place today? Finally, the Savannah workshop suggests that even when there is a stated need for information from the science community, unless the question is asked in a fashion which will allow it to use information readily available, or unless it is possible to transfer a methodology from another field to organize the information in an acceptable fashion, the science community, even when it wants to help, is often inadequate to the task.

APPENDIX A : ##

PROCEEDINGS OF A WORKSHOP ON
INTEGRATED ASSESSMENT FOR ENERGY-RELATED ENVIRONMENTAL STANDARDS,
Berkeley, California,
November 2 and 3, 1978

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Sponsored by
Assistant Secretary for Environment
U.S. Department of Energy

Contents

I. Preface.....	A-2
II. Integrated Assessment for Energy-Related Environmental Standards: An Introduction.....	A-3
III. Synopses of Background Papers and Discussions.....	A-7
Environmental Data Bases and Integrated Models as Assessment Tools: A Critical Survey of Accomplish- ments, Potential, and Limitations.....	A-8
Tools for Measuring Pollution Damage Costs: A Critical Review.....	A-13
Integrated Assessment: A Case Study of the Federal Water Pollution Control Act.....	A-17
A Regulatory Approach to the Problems of Reclamation of Strip-Mined Lands.....	A-20
EPA's Evaluation of the Environmental Impacts of New Source Performance Standards for Fossil-Fuel Power Plants.....	A-23
A Case Study of Regulation of Mobile Sources of Air Pollution.....	A-26
IV. Synopses of Round-Table Discussions.....	A-30
Better Mechanisms for Integrated Assessment.....	A-30
Constraints on Implementing Better Mechanisms.....	A-31
Directions for Further Research on Integrated Assessment.....	A-32
V. Some Concluding Observations.....	A-35
VI. Full Texts of Background Papers and Written Responses of Discussants.....	A-37

I. PREFACE

The Workshop on Integrated Assessment for Energy-Related Environmental Standards was held at the University of California's Lawrence Berkeley Laboratory on November 2 and 3, 1978, under the sponsorship of the Office of Technology Impacts, Office of the Assistant Secretary for Environment, U.S. Department of Energy.

The term "integrated assessment" refers to analysis that attempts to elucidate the full range of consequences of a given policy action -- all the costs and benefits, whether economic or environmental, intended or unintended, prompt or delayed -- in order to determine whether the action will make society better or worse off in the aggregate, and by how much. The workshop brought together individuals from the public sector, academia, and various research institutions who have developed, studied, or applied aspects of integrated assessment in the context of environmental standards affecting energy technologies. The workshop's purpose was to review the state-of-the-art of integrated assessment for environmental standards, and to draw lessons from the history of applied integrated assessment in this arena that could improve the relevance of such analysis for future standards decisions.

Background for the workshop was provided by two survey papers and four case studies prepared under contract to the Office of Technology Impacts by the Energy and Resources Group of the University of California, Berkeley, and the Energy and Environment Division of the Lawrence Berkeley Laboratory. The workshop proceedings that follow comprise: (a) a brief introduction to the concept of integrated assessment; (b) synopses of the background papers and of the discussions they catalyzed at the workshop; (c) synopses of round-table discussions focused on the future of applied integrated assessment and of integrated assessment studies; and (d) appendices consisting of the full texts of the background papers and written responses prepared by some of the invited discussants.

II. INTEGRATED ASSESSMENT FOR ENERGY-RELATED ENVIRONMENTAL STANDARDS:

AN INTRODUCTION

John P. Holdren

Environmental impacts of energy technologies arise from many stages in the flow of an energy source from discovery to end-use (e.g., mining, processing, combustion), propagate via disruptions in many media (e.g., air, water, soil), and manifest themselves as many different undesirable effects (e.g., occupational disease, public disease, property damage, loss of service functions performed by ecosystems)¹. Attempts to control environmental impacts have evolved in a piecemeal fashion, focusing typically on one stage at a time, one medium at a time, one effect at a time. But the pieces are not independent, and the damages associated with each cannot be independently minimized. As the degree of control sought in different sectors has increased, the nature of the troublesome linkages has become clearer: controlling air quality may impose additional burdens on water and soil; emissions restrictions at the combustion stage may push impacts back to the processing stage (as, e.g., in solvent refining or liquefaction of coal); and reductions in public disease may be bought at the expense of occupational health. The substantial inability to determine systematically and objectively whether any given "tradeoff" of the kind just described leaves us better or worse off in the aggregate -- that is, the lack of an integrated environmental assessment capability -- is emerging as the central problem of contemporary environmental policy.

The nature of the assessment task is made apparent by considering the steps in environmental science, environmental economics, and policy analysis that go into it.

The environmental-science part of the assessment task can be broken down into examination of the following stages in the generation of consequences for human well-being²:

- (1) the sources of impacts on the environment, in the form of specific activities in the application of specific technologies for getting and using energy (e.g., exploration, mining, beneficiation, transport, storage, conversion, transmission, or end-use in the coal or uranium fuel cycle);
- (2) the insults that emanate from these sources, meaning what is put into, taken out of, or otherwise done to the environment (including, e.g., consumption or pre-emption of resources, material effluents, electromagnetic radiation, heat, noise, other physical transformation, and sociopolitical influences);
- (3) the stresses the insults cause*, to which humans or other components of the environment at risk are exposed (e.g., altered chemical concentrations in air, water, soil, and biota; altered meteorology and hydrology; loss of wildlife habitat);

* Note that, for some kinds of disruption, the insult and stress can be one and the same (e.g., paving over a salt marsh for a refinery), while for others insult and stress may be separated by complicated environmental pathways (e.g., the insult of SO₂ emissions translated weeks later and hundreds of kilometers away into the stress of acid rain). Similarly, consequences can be the direct result of a stress (e.g., loss of recreational value of a beach due to an oil spill) or can follow from a complicated set of responses of intervening environmental systems and affected processes (to pick an extreme example, human skin cancer from enhanced ultraviolet radiation due to depletion of stratospheric ozone catalyzed by excess nitrous oxide produced by changes in the populations of denitrifying soil bacteria owing to soil acidification by acid rain -- a speculative but conceivable chain)³.

- (4) the consequences for human well-being, consisting of or resulting from the responses of the components of the environment at risk to the stresses imposed (e.g., death, injury, disease; economic loss; loss of environmental amenities; undesirable social or political change).

A number of obstinate problems in environmental science block the analyst's path between source and consequence. Most intractable among these are: (a) problems of pathways linking insult and stress (e.g., the problem of relating ambient air quality to emissions), wherein processes of physical transport, chemical transformation, and biological concentration can interact with awesome complexity; and (b) problems of "dose-response" relations linking stress and consequence (e.g., the problem of relating excess mortality from respiratory disease to urban air quality), wherein unscrambling the effects of multiple agents, many at low doses and some doubtless interacting synergistically, is a nightmare for experimentalists and statisticians alike. Problems of "pathway" and "dose-response" are at least equally formidable when the impacts are sociopolitical rather than biogeophysical.

When, notwithstanding these difficulties, some estimates of consequences materialize, the environmental-economics part of the problem begins. Here the task is valuation, preferably in monetary terms, for comparison with the economic benefits of the activity generating the impacts or with the anticipated costs of controlling them. Actually, for each type of consequence the environmental economist would like to be able to quantify each of four different classes of costs (all of which depend on the strategy adopted for dealing with the consequence):

- (1) damage costs associated with absorbing the consequences (e.g., dollar valuation of losses in the form of premature deaths, illness, property damage, and so on);
- (2) avoidance costs associated with measures taken to escape damages (e.g., by moving elsewhere or buying an air conditioner to avoid damages to health from air pollution);
- (3) abatement costs spent to reduce the insults that lead to consequences (e.g., costs of stack-gas scrubbers, water-treatment plants, and so on, but including also the costs of simply doing less of whatever is producing the insults, e.g., generating less electricity);
- (4) transaction costs associated with research, planning, administration, communication, and monitoring for pollution control⁴.

The difficulties confronting economists seeking to evaluate these costs are great. Notable among those difficulties are: (a) resistance of many classes of consequences, particularly those arising from disruption of environmental and social processes, to quantification; (b) lack of agreed-upon procedures for monetary valuation of even those consequences that can be quantified; (c) uncertainty concerning monetary abatement and avoidance costs until the specific abatement and avoidance schemes under consideration have been carried out on a substantial scale; (d) existence of non-monetary (external) impacts of the abatement and avoidance procedures themselves, which impact must, in turn, be avoided, abated, or absorbed as damages (and so on ad infinitum); and (e) problems associated with separation of costs and benefits geographically, over time, or across socioeconomic classes.

If economists had tidy solutions for all these problems -- and thus could provide cost functions in the four categories listed above for all the important types of environmental consequences -- the tasks of the policy analyst and policy maker would be rather straightforward: find and implement the set of policies that augments the market in such a way that the sum of all the costs in the four categories is minimized. In reality, of course, just as the shortcomings and uncertainties of environmental science handicap the environmental economist, who must put values on consequences that environmental science defines, so do the imperfections of environmental economics add to the handicap that is passed on into the policy arena, where someone must decide which of the galaxy of possible policies for reducing environmental costs should be adopted.

In language popular with policy analysts, the problem of integrated assessment is described in terms of "tradeoffs". One knows, that is, that a policy designed to suppress a specific impact not only will

have a cost in dollars and other resources, but also may simply displace the problem on one or more of many axes -- for example, displacement from:

- o one energy source to another
- o one fuel-cycle step to another
- o one pollutant to another
- o one medium to another
- o one type of consequence to another
- o one class of victim to another
- o one place to another
- o one time to another.

Integrated assessment means taking all such tradeoffs into account in determining whether or not the policy in question makes us better or worse off⁵. Among the questions the work of the Office of Technology Impacts seeks to illuminate related to this issue are the following: Just how great are the intrinsic handicaps imposed by the state-of-the-art in environmental science and environmental economics on the policy community confronting this integrated-assessment task? What are the prospects for reducing these handicaps in time? How might the formation of environmental policy best proceed given those elements of the handicaps that will not soon be reduced?

Notes

1. A survey of the complexities of impact analysis is Robert J. Budnitz and John P. Holdren, "Social and Environmental Costs of Energy Systems", Annual Review of Energy, vol. 1, pp. 553-580, 1976.
2. This and parts of this subsequent discussion are adapted from John P. Holdren, "Environmental Consequences of Energy Technology: Bringing the Loss of Environmental Services Into the Balance Sheets. Part I: A Framework for Analysis", Draft Report for the Council on Environmental Quality, Executive Office of the President of the United States, October 1977.
3. A systematic discussion of these sorts of complications is given in John Harte, Charles Blanchard, Mohamed El-Gasseir, and Shelley Tanenbaum, "Environmental Consequences of Energy Technology: Bringing the Loss of Environmental Services into the Balance Sheets. Part II: Services, Disruptions, Consequences", Draft Report for the CEQ, October 1977.
4. These categories and approaches for dealing with them are treated at greater length in Council on Environmental Quality, Environmental Quality - 1975: The Sixth Annual Report of the CEQ, Government Office, Washington, D.C. 1976, Chapter 4, "Environmental Economics".
5. A useful discussion by a policy analyst who has grappled with those issues extensively is Peter W. House, The Quest for Completeness: Comprehensive Analysis in Modeling, Indicators, Gaming, Planning, and Management, D.C. Heath and Co., Lexington, Mass., 1976.

III. SYNOPSIS OF BACKGROUND PAPERS AND DISCUSSIONS

**"Environmental Data Bases and Integrated Models as Assessment Tools:
A Critical Survey of Accomplishments, Potential, and Limitations"**

John Holdren, John Harte, Kathy Tonnessen
Energy and Resources Group
University of California, Berkeley

We use the term "integrated assessment" to describe attempts to determine whether any given set of actions in environmental policy related to energy (e.g., imposing an emissions standard) will make society better or worse off in the aggregate, and by how much. Such a determination entails identifying, characterizing and weighing all of the consequences of the actions: costs, risks, and benefits; economic and environmental; intended and unintended; prompt and delayed. (We interpret environmental effects broadly to include the sociopolitical as well as the biogeophysical environment, and we note that the line between environmental and economic effects is not sharp.) In this context, we describe as "integrated models" those computer models, devised to assist the integrated assessment task, that incorporate elements from both economics and environmental science to illuminate the consequences of alternative policies.

The present paper reviews what has been accomplished to date in building and using such integrated models and the environmental data bases they require as inputs, the potential of these tools for further development and application, and the nature of certain fundamental limitations that must be recognized if such tools -- even much improved ones -- are not to be abused. We conclude with some preliminary observations on a topic of supreme importance to today's policy makers: given the persistent inability of economics and environmental science to perfect the tools that integrated assessment seems to require, how should policy choices be made?

The core of the integrated-assessment problem is identification, characterization and assessment of environmental effects. Reducing certain of these effects is the goal of abatement policies, so evaluating the specific benefits of reductions is the major part of determining the benefits of the policies; and, since policies to abate one set of effects may aggravate others, evaluating such "secondary" effects is an important part of determining the costs of the policies as well. In order to evaluate the state-of-the-art in models and data bases for assessment of environmental effects of energy technologies -- what has been attempted, what has been accomplished, what remains to be done -- it is useful to have a logical framework that illuminates the structure of the assessment problem and decomposes it into analyzable tasks. We build our framework on the sequence, sources → insults → stresses → consequences.

Data Bases

Central to the task of integrated assessment for energy-related environmental standards is the availability of data on the quantifiable environmental effects of activities at the various stages of the fuel cycles of different energy sources. The two largest and most useful such data bases are the Matrix of Environmental Residuals of Energy Systems/Energy Model Data Base (MERES/EMDB) maintained by the Energy/Environmental Data Group at the Brookhaven National Laboratory and the data base embedded in the Strategic Environmental Assessment System (SEAS), developed at EPA and now maintained for the Department of Energy by the MITRE/METREK Division and other contractors. Both these data bases are strongest in their coverage of resource use, occupational safety in facility operation, and emissions of criteria air pollutants, radioactivity, and certain other water pollutants. Except for occupational safety, information going beyond "insults" in the impact-assessment chain is scarce in these data bases; their usefulness is also somewhat impaired by omissions of data for important kinds of processes and insults, large uncertainties in many of the data that are provided, and loss of information owing to geographic aggregation.

Integrated Models

The most ambitious energy-economic-environmental model in existence is SEAS, which is actually an interdependent set of models and data bases capable of being run in various sequences and combinations. SEAS has been used in a variety of analyses that could be termed "integrated assessments" -- for example, by and for the CEQ, EPA, National Commission on Water Quality, Bureau of Land Management, the Department of Energy, and, most recently, a study conducted at the Solar Energy Research Institute of the environmental effects of large-scale introduction of solar energy technologies in the U.S. A second set of integrated energy-economic-environmental models is maintained at the Brookhaven National Laboratory and has been used in integrated-assessment exercises by the Energy Research and Development Administration, the Department of Energy, and others.

Issues and Directions for Improving Integrated Assessment

Information brought to bear on the integrated-assessment task tends to suffer from deficiencies with respect to:

- (1) comprehensiveness/completeness (some links between contemplated actions and well-being do not get identified, and for some that are identified the information needed to characterize the link is missing);
- (2) quantification/accuracy (many effects that can be identified and characterized cannot be quantified, and much of what has been quantified is inaccurate or characterized by very large uncertainties);
- (3) comparability/valuation (even among effects that have been accurately quantified, the units of measurement are often incommensurable, which frustrates comparative valuation, and even where valuation is possible the capacity to weigh alternate distributions of costs and benefits among winners and losers is absent).

Much attention has been given in the assessment field to applying economic tools to the last class of difficulties -- that is, to seeking monetary measures of the consequences or actions, so that direct comparison of alternatives is possible. This preoccupation with economic-valuation, although understandable given the necessity to make decisions somehow and the desire of decisionmakers to be able to defend what they have decided, is fraught with pitfalls: the valuation schemes are contingent on assumptions of which many users of the results are quite unaware; and the apparent concreteness of dollar figures promotes the possible misconception that the most important effects necessarily have been captured in those figures.

Our review of the analytical and information basis for integrated assessment has in fact led us to the preliminary conclusion that, in the development of this basis so far, emphasis on economic valuation has been accompanied by insufficient attention to the distribution of costs, emphasis on quantification has been accompanied by insufficient attention to problems of accuracy/uncertainty, and emphasis on both quantification and valuation has been accompanied by insufficient attention to problems of completeness.

If the usefulness (to decisionmakers and the public) of environmental data bases, integrated models, and other analytic tools for integrated assessment is to be increased and abuses of these tools avoided, it will be necessary to devote much more systematic attention than in the past to the question of what the tools omit, as opposed to what they contain. More specifically, both the efficient allocation of technical resources aimed at improving integrated-assessment capability and the proper use of the tools that already exist require attention to these basic questions:

- (1) What can one say about the relative importance of what has been left out or deemphasized in present tools compared to what is well covered?

- (2) How resistant are the most important gaps to being substantially reduced in time by the progress of knowledge (partly a function, of course, of the resources applied to the task)?
- (3) What approaches could lead to improved decisionmaking in the face of resistant uncertainties and holes in available data and tools?
- (4) What is the relative cost-effectiveness at this point of applying resources to improving data bases and integrated models themselves, versus using the resources to increase knowledge in the underlying environmental and social sciences, versus using the resources to seek ways to deal in the policy arena with persistent imperfections in scientific knowledge and analytical tools?

It is to these questions that efforts to improve integrated assessment should be addressed.

DISCUSSION OF HOLDREN/HARTE/TONNESSEN PAPER

Roger Shull, Office of Technology Impacts, U.S. Department of Energy

Shull noted that the paper's discussion of the history of "integrated models" is incomplete. When, for example, did people first start to integrate input/output (I/O) models of the economy with environmental information? Did Leontief discuss environmental-impact coefficients? Before any attempts at comprehensive national models were made, moreover, there were models of individual air basins and watersheds. Walter Isard's work at the University of Pennsylvania, applying environmental coefficients to an I/O model of the Delaware River Basin, comes to mind. (Good work continues to be done at the regional level, as for example the work of Walter Spofford of Resources for the Future on a linear programming model for standards implementation in the Delaware Basin.) One of the early accomplishments of the SEAS effort that perhaps deserves more emphasis was to bring together economists and environmental scientists in a close, collaborative effort.

Shull suggested that there is no longer any serious argument about whether to use integrated models in policy analysis; the arguments are only about whose models are better. For the models are being used; they have been "institutionalized" as an ingredient in government policy decisions for the past five years. Of course, it should be understood that the aim of systems analysis is to assist decisionmakers, not to replace them. Early optimism in the systems-analysis field about using quantitative objective functions with constraint equations effectively to make choices for the decisionmaker was misplaced. The main thrust today recognizes that decisions will remain primarily political and that the proper role of systems analysis is simply to assist the decisionmaker by providing structured sets of relevant data to illuminate alternatives. (The paper might have cited Ida Hoos' book on the use and misuse of systems analysis, Systems Analysis and Public Policy, on these issues.) In this context, the most important questions are how best to condense the relevant data for use in decisionmaking by politicians, and how to incorporate non-numerical considerations.

In response to the paper's emphasis on the inadequacies of analysis that stops at residuals, Shull noted that it is sometimes enough for the purposes of decisionmaking to know the residuals. An increase in residuals, after all, is almost always bad, and a choice between two technologies can sometimes be made, therefore, simply on the basis of which one produces the smaller residuals.

Shull commented, finally, that the paper's conclusion -- on the issue of whether the right questions are being asked in integrated assessment and with the right emphasis -- is on the right track.

Michael Yokell, Solar Energy Research Institute, Colorado

Yokell provided several pages of written comments in addition to his oral discussion. The two are combined here, omitting only a few factual errors Yokell found in the paper, which have since been corrected there.

Yokell found the paper good on the whole. Perhaps the most serious omission was the lack of discussion of the need to integrate into assessments the impact of environmental regulations on the economy as a whole. In this connection, Yokell noted the current "hoopla" being created by President Carter's Council on Wage and Price Stability, a subgroup of which is examining the impact just referred to in the apparent hope of reducing environmental regulations.

Among Yokell's other points were:

- One must be careful not to count the impacts of resource use twice -- once in physical units and once in economic units. Economic units may not properly account for the resource-depletion effects of use, but the dollar value of a resource cannot be added to a measure of its physical depletion.

- If "net energy accounting" is to be of any use at all (which is doubtful), one must indeed draw the system boundary widely and count the energy used to manufacture that portion of a train which depreciates in the process of hauling coal to an electricity generating plant, etc.

- Concentrated damages are not always perceived as being higher than equivalent spread-out damages. The non-degradation of Class I air pollution areas is a case in point.

- Many of the "boxes" in RESGEN's taxonomy of environmental effects are empty, but there is still an enormous amount of data involved. For approximately 500 sectors and 100 facilities, multiplied by about 40 residuals, there would have to be 24,000 entries to completely fill in the boxes. About 37% of all boxes in all modules are actually filled.

- Even so apparently straightforward a process as measuring loss of crops due to pollution actually involves valuation. If a crop is damaged due to air pollution, it may be more economic to shift to a more pollution-resistant crop. In this case, crop losses would be only the difference between the value of the first and second crops produced, rather than the entire value of the first crop lost due to pollution.

- Separating the processes of option-defining and option-selecting, as suggested in the paper, is a very expensive proposition. It requires the creation of two separate bureaucracies, each with its own staff of experts. It might be justified in extreme cases (for example, in the split-up of the AEC into ERDA and the NRC), but it is doubtful that it is always (or even often) justified.

- Although there has been much discussion by economists, there has actually been very little applied work in estimating the monetary damages due to anthropomorphic environmental stresses. Even the work that has been done has been widely ignored. It is not clear that even EPA has taken environmental benefit-cost analysis seriously.

- One class of models that was not discussed is "systems dynamics" models. No systems dynamics model has been built to date which focuses precisely on the energy-environment tradeoffs in the next quarter century in the U.S.: the model described in Limits to Growth is more general, and the systems dynamics model of the U.S. energy system, Fossil 1 (FOSSIL I, Introduction to the Model, Dartmouth Systems Dynamics Group, Hanover, NH, July, 1977) does not include environmental parameters.

- The version of SEAS now actually running uses an energy module considerably less complicated than that described in the paper. ESNS, for example, does not receive forecasts of energy use from elsewhere in the model. Total energy demand is specified exogenously. INFORUM is run, and total energy use implicit in INFORUM is calculated. If it is higher than that specified exogenously, energy use fed to

ESNS is proportionately reduced and the system run iteratively until the target energy demand is reached. EIM, moreover, is not a supply/demand matching model; it simply calculates the amount of investment in each input-output sector required to produce a given amount of energy from a given facility in a given year.

Finally, Yokell noted that many of the problems described in the paper are aggregation problems. The fundamental question here is what is the appropriate level of aggregation for the analysis at hand. Water consumption, for example, might be a useful indicator when comparing some energy systems in water-short areas, but it obviously hides many variables of interest. If we wanted to examine the impact of energy development upon water in the West, measures of gross consumptive water use would be only the first step.

General Discussion

Some of those present noted that the term "integrated assessment" means different things to different people, and that it is necessary to be specific about the respects in which an assessment is integrated; i.e., integration across regions, across technologies, across time, between economic and environmental considerations, and so on. The authors reiterated the position that, for the purposes of this work, integrated assessment means incorporating all the kinds of integration needed to help a policy maker determine whether a given action would make society better or worse off overall. It was agreed that the context in which the information will be used plays an important role in determining how much and what kinds of integration are necessary. The paper tried to explore the boundaries of the extent to which present data bases and models permit integration in various dimensions, but did not mean to imply that every problem will test the capabilities of such models and data bases in every dimension of integration.

The view was expressed that the paper's statement that a model is only as good as the data put into it is uninformative. A model is also only as good as its algorithms, the choice of problems on which it is exercised, the intelligence applied to the interpretation of the output, and the way in which the results are presented to decisionmakers. Each of these elements is potentially the weakest link, and none is more fundamental than the others.

"Tools for Measuring Pollution Damage Costs: A Critical Review"

Anthony C. Fisher
Energy and Resources Group
University of California, Berkeley

This paper provides a short critical review of some tools for measuring pollution damage costs.

Kinds of Costs Associated with Pollution

Two kinds of costs are ordinarily associated with pollution:

- o Costs of pollution itself -- involving damage to things that affect human welfare directly or indirectly, such as health, the productivity of ecosystems (fish, forests, crops), and so on.
- o Costs of controlling pollution -- the additional expenditures entailed by changing in some respect the pattern of economic activity that generates pollution.

For example, a firm might have to shut down and move to a new location, or invest in control equipment. These are, in fact, the kinds of costs non-economists often seem to have in mind when they think of economics and pollution. But costs of environmental damage are just as much economic costs as those involved in installing a piece of control equipment. The distinction can get blurred, as in the defensive expenditures by pollution recipients. A victim of polluted air may move his residence, or less drastically, purchase an air conditioner, or plant some trees, all with a view toward reducing the impact of the pollution.

Still another kind of cost plays a role in discussions of pollution control policy: the cost of administration. Since pollution control is a public good, it will ordinarily result from a public policy. And as taxpayers and victims of bureaucratic regulation doubtless understand, the cost of making and enforcing policy can be substantial. Costs of controlling pollution and defending against it can also be substantial, of course.

Again, this paper is concerned only with the costs of pollution damage and the tools for measuring these costs.

Components of Damage Cost Estimates

The framework is not peculiarly economic. That is, the assessment tools are useful only in conjunction with contributions by researchers from other disciplines -- engineering, marine biology, meteorology, and so on. Of the several steps in the process of measuring damage costs, only the last, inferring costs from physical measures of damage, is solely the responsibility of the economist, though economics plays a role in the first, the transition from activity to emission levels, and economists have also been involved in determining the statistical relationships between pollution concentrations and physical consequences, such as impacts on health.

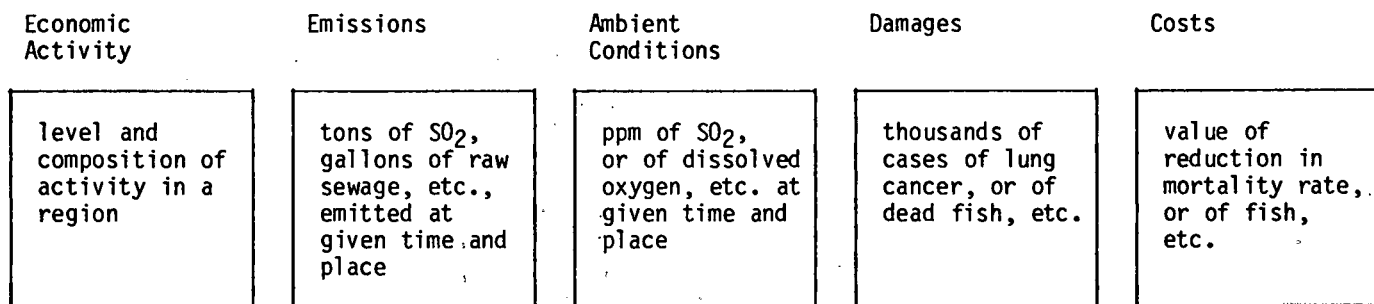


Figure 1. Steps in Going from Activity to Costs

An alternative approach to valuation involves estimating costs directly from pollutant concentrations or ambient conditions. For example, property values are compared in polluted and unpolluted areas, and the difference (controlling for other influences) attributed to pollution.

Difficulties in Imputing Values to Physical Damages

Consider, for example, what looks like a very straightforward case: imputing value to crop losses. The obvious value is market price. But suppose crop loss is substantial, and demand is inelastic. Then there will be an impact on price, which, in a general equilibrium system, will affect the prices of related commodities. The change in consumer welfare triggered by the pollution may not be simply measured by the quantity of affected crop times "the" price of the crop. A complete analysis would have to take into account the welfare effects of the related price changes -- as well as of the crop price change. Of course, it may be that the effect on price is negligible, in which case the partial and general equilibrium adjustments can be ignored. But the theoretical possibility is real.

Another kind of complication can arise from the possibility for defensive action on the part of the pollution victim. Suppose some such defensive action or adjustment is not only possible but less costly (to the victim) than the damage that would otherwise result. For example, instead of suffering heavy crop loss, a farmer might plant a pollution-resistant strain. Suppose the original crop loss would have been valued at \$1,000; loss to the resistant strain would come to \$500, and the extra cost of planting it would be \$100. Then the farmer is better off adjusting his planting and absorbing a loss of \$600 rather than not adjusting and taking a loss of \$1,000. The implication for cost estimation is that a laboratory experiment that studied the effect of pollution on the original crop would over-estimate damages, placing them at \$1,000 rather than \$600.

Now suppose time (costly) adjustment has already been made, and an experiment or field study looks at damage to the new crop. In this case the estimate would be low, as it ignores the cost of adjustment (the \$100 in our example). The point is not that cost estimates should not be made; rather, it is that they must be interpreted with some care, in the light of economic theory. Then we might at least be able to say that a given estimate is an upper or lower bound, a useful result.

Valuing Human Health and Life

Though the problems for estimation posed by general equilibrium price changes, and adjustments by pollution recipients, could be substantial, perhaps the most vexing question in pollution damage studies is how to put a value on human life. The same problems exist here as in estimating, say, crop losses. But

in addition, there is the rather obvious lack of any measure of value analagous to crop price. This section of the paper briefly reviews some of the approaches that have been taken to valuing life-saving programs such as pollution control.

Difficulties in Direct Estimation

Apart from the obvious statistical problems, the major difficulty in the property value studies is in determining whether observed property value differences fully reflect consumer willingness to pay for a clean environment, or the compensation required to live in a dirty one. This depends on the "openness" of the area in question. If there are no cost or other barriers to movement, consumer surpluses will be competed away, and reflected in property values.

Another method for inferring the value of damages directly from ambient conditions is to survey a sample of the affected parties. Problems with such surveys are well known, a major one being the incentive to respondents to not reveal their preferences honestly.

Decisionmaking Under Uncertainty

A number of reasons have been suggested for believing that our knowledge of the costs of pollution damage is highly uncertain. In this section a theorem about decisionmaking under uncertainty, where however the uncertainty is reduced with the passage of time, is described. The point of the theorem is that an action having an uncertain adverse impact that is difficult to reverse has an additional cost attached to it, the value of the information about the impact that would be acquired during the period that it is not undertaken. The implication is, go slow with such actions, even slower than a conventional benefit-cost analysis would suggest.

Relationships Between Different Approaches to Cost Estimation

Is a property value study an alternative to a health impact study? Or should separate estimates be made and combined? In the best of all possible worlds for the researcher, a market value measure such as property value would be sufficient. If people correctly perceived pollution and its effects, and if theoretical conditions, including openness, were satisfied, all of the effects -- on paint jobs, on health, on visual amenity -- would be negatively capitalized into land values and rents.

Since these are big if's, and we don't live in the best of all possible worlds, what can be said? It seems likely that at least some of the effects are perceived, and enter into individual decisions on how much a piece of property in a given area is worth. This would be true for tangible items, like soiling and corrosion of structures. It would also be true for intangible items, like discomfort, or an obscured view. On the other hand, it would probably not be true for health effects. Effects on structures, and on visual amenity, are perceived to some degree, and effects on health to a lesser degree.

Although property value studies generally deal with residential property, similar arguments might be made for agricultural, commercial and industrial property. The damaging effects of pollution on the crops, forests, commercial buildings or industrial processes at a site would, in theory, be negatively capitalized into the value of the site. Effects on the health of workers might not be, at least not to the same degree.

Where does this leave us? The damages estimated in property value and health should probably be added together rather than viewed as alternatives. On the other hand, adding structural damage to a figure reliably estimating a property value would probably represent double counting. Where a summary measure like property value is not available, damages from separate effects should, of course, be added together.

DISCUSSION OF FISHER PAPER

Paul Portney, School of Public Policy, University of California, Berkeley

Portney began his remarks by emphasizing the complex and crucial links between environmental regulation and the economy. He felt that the paper was a good survey, with no important gaps. Portney singled out a couple of points for emphasis. First, he mentioned the distinction between pollution damage costs and pollution control costs. The damage costs are the benefit from incurring pollution control costs, although excess administrative costs also accrue. Integrated assessment (IA) must balance damage costs with abatement costs. Second, he mentioned the importance of defensive adjustments made by pollution recipients. If such adjustments (e.g., planting a lower value, pollution-resistant crop) have already been made, damages may be underestimated. It is very difficult to assign values to this type of averting behavior.

Portney also had a couple of quibbles with the paper. First, with respect to whether the Lave and Seskin results are disproved by recent experience with reduced sulfate levels in New York City, Portney pointed out that health effects may have latency periods, so that there has not been sufficient time to observe a change. Second, with respect to whether people perceive pollution and its effects around their place of residence, Portney feels that perception may be improving due to the widespread publicity given environmental problems in recent years. If this is true, then studies which relate property value differences to pollution differences may become more reliable.

Wilbur Steger, CONSAD Research Corporation, Pittsburgh, Pennsylvania

Steger stated that he found one serious omission in Fisher's paper. There was no consideration of risk assessment. Steger felt that economists must go beyond simple cost/benefit (C/B) analysis, and introduce non-cost issues through risk/benefit/cost assessment. Using the traditional C/B framework, it is difficult to relate macroeconomic effects (e.g., income and employment impacts) to overall economic efficiency.

Steger noted that economists could have a much greater impact if they would participate more fully in the political decisionmaking process. This would require an understanding of the sequential decision-making process, in order to most effectively apply economic analysis. Risk assessment is an important part of decisionmaking problems today. Economists must also consider and value the costs, benefits and risks of delay in the formulation of public policy.

General Discussion

The emotional impacts of many types of valuation, particularly those dealing with human health and mortality, can have important effects on the political process. The derived values are never very certain, due to difficulties with applying epidemiological data, and with relating emissions to ambient conditions. Thus, it is particularly important for those engaged in C/B analysis to honestly express the range of the uncertainty in their data. Synergistic impacts should also be included in any analysis, although these effects are often very difficult to anticipate and characterize.

Several of the veteran decisionmakers in the group complained that economists and other analysts have a tendency to try to present final decisions to decisionmakers, or to try to use objective models for making decisions. Decisionmakers feel that they already use sophisticated techniques in their deliberations. What they really need is better information and more reliable data. The appropriate role of an analyst is to lay out the options, and describe the potential consequences to the decisionmaker. In some cases, an analyst's desire to affect a decision may lead him to overstate his case.

"Integrated Assessment: A Case Study of the Federal Water Pollution Act"

Charles L. Blanchard
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University of California, Berkeley

This paper is a case study of the Federal Water Pollution Control Act, as amended in 1972 and 1977. Our purposes are, first, to ascertain the manner in which Federal environmental policy has been formulated for one major regulatory effort; second, to determine the extent to which this manner of formulating environmental policy incorporates systematic and integrated assessment methods; and finally, to determine whether or not misguided policies may be attributed to an absence of integrated assessment methods. We emphasize examination of the costs of abatement technology, energy requirements for abating water pollution, and non-water quality environmental impacts occurring as a result of water pollution abatement. Each is a tradeoff, in that the effect occurs as a result of improving water quality by reducing discharges. Each should be considered a cost of water pollution abatement.

An example of one tradeoff is the increased consumptive use of water resulting from the thermal effluent limitations promulgated by EPA. We limit ourselves to discussion of the extent to which integrated assessments of tradeoffs such as this have been incorporated into the promulgation of effluent limitations, and describe reasons why tradeoffs have seldom been assessed in an integrated manner.

The findings of this investigation, in summary form, are as follows. The actions of EPA in promulgating effluent limitations as required by the FWPCA bear little resemblance to a systematic and integrated approach to formulating environmental policy. This may be attributed to two primary causes. First, EPA's major responsibility under the FWPCA is to attain the water-quality objectives of the Act. Second, since EPA is an agency with a mission, it has tended to err on the side of environmental protection by design; the Agency has been aware that mistakes are inevitable, and has acted so that the inevitable mistakes will not hinder the cause of environmental quality.

Although an entirely satisfactory analysis of the motivations of the decisionmakers at EPA is undoubtedly impossible, our study examines EPA's interpretation of its responsibilities under the FWPCA, and concludes that EPA's consideration of tradeoffs has favored water-quality objectives, despite the fact that the FWPCA does require EPA to consider non-water-quality objectives. In part because the law, as viewed by EPA, does not specify the manner in which EPA is to consider them, non-water-quality objectives are usually treated as secondary considerations.

The law leaves much of the determination of the water-quality objectives to the discretion of EPA. For example, EPA was to determine ambient standards consistent with the rather vague goal "that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983" [section 101(a)(2) and section 304(a)(1), (2)]. Further, the specification of best-available-control technology was left to the discretion of EPA. EPA thus had considerable latitude in the setting of effluent standards.

Examination of the standards promulgated by EPA indicates that EPA has interpreted the Congressional intent so as to favor rather stringent water-quality objectives. When challenged in court, EPA has argued that its interpretation is within its discretion, that Congress made the fundamental determination that attainment of the water-quality objectives is desirable, and that the Agency's responsibility is to attain the objectives. The courts have generally upheld EPA's interpretation of the Congressional mandate. The lack of integrated assessment attendant upon this approach has fostered some policies that appear misguided when viewed in a broader context.

This case study illustrates the importance of the motivations of an agency and of the decisionmakers within the agency. While informal modes of integrated assessment occur within an agency, the decision-making process is not nearly as rational and analytical as an ideal integrated assessment would be. For example, many of the decisions examined later in this paper were made by EPA under the pressure of tight deadlines. Further, EPA may combine numerous environmental agencies within one organization, but there remain barriers between these formerly independent agencies. Thus, water-quality goals may be established without a full understanding of the consequences for air pollution. This point holds also for effects, such as energy use, that are not within the jurisdiction of EPA. Finally, decisions will be altered according to the extent to which affected parties can bring pressure upon the decisionmaking body. These parties include other governmental agencies, industry, and the general public. This is an aspect of decisionmaking that has played an important role in the promulgation of effluent guidelines under the FWPCA.

Our attention here is confined to the methods used by EPA in promulgating effluent regulations, and focuses on the extent to which EPA's methods represent an integrated assessment. Since the motivations of decisionmakers and the pressures of affected organizations play such an important role in the decisionmaking process, further examination of these topics would be desirable. Certainly, any formalized methods of integrated assessment must somehow deal with these factors. Further discussion of the importance of affected constituencies and of the motivations of decisionmakers is unfortunately beyond the scope of this paper.

DISCUSSION OF BLANCHARD PAPER

Gerald Hansler, Executive Director, Delaware River Basin Commission

Hansler stated that he agreed with approximately 80% of the paper. This included the contention that EPA was "biased on the side of the environment", as well as the analysis of the EPA's implementation of the Federal Water Pollution Control Act (FWPCA).

Hansler disagreed with the argument that the apparent absence of integrated assessment on the part of the EPA was due to the requirements of the FWPCA. Rather, the absence was due to the way in which the EPA chose to interpret the Act. Hansler argued that there is considerable latitude for the Administrator of the EPA, so that the EPA may interpret such basic points as the definition of a pollutant and the meaning of zero discharge of pollutants much less strictly than it has previously.

Hansler recommended the use of guidelines that are general enough to apply on a case-by-case basis. Such guidelines would have to be flexible. Hansler indicated that the current laws could be much more flexible if the EPA exercised its discretion to interpret the FWPCA somewhat differently than it has.

Hansler further noted that the EPA has not yet given sufficient attention to the problem of water consumption. Hansler stated that even in the Delaware River Basin, the consumptive use of water is generating problems.

James Russell, Department of Energy, Region 9

Russell suggested that the case study should include further analysis of the EPA's bias toward the environment. He particularly recommended discussion of the roles of Leon Billings and Edmund Muskie in formulating the legislation.

Russell also suggested that the case study should consider tradeoffs involving energy and water in greater detail. He mentioned one "real life" problem (a coal-fired facility, proposed for location in

Nevada), and recommended more extensive discussion of such problems. He also noted that in some regions (e.g., the Delaware River Basin), IA is now occurring.

Finally, Russell argued that information is important to IA processes. In particular, the types of information available, to whom it is available, and what is actually done with it are very important.

General Discussion

Three factors have hindered the development of IA methodology in the EPA. First, due to its internal structure, communication between divisions responsible for different media is inadequate. Second, water pollution control strategies have been geared to controlling traditional problems such as BOD, and adequate data are not available for dealing with some of the new pollutants. Finally, the best available control technology approach is easier than developing IA methods.

There was some disagreement as to whether IA methods should be utilized on a case-by-case basis, or whether the decisionmaking process itself should be modelled. The problem of properly motivating decision-makers was discussed.

"A Regulatory Approach to the Problems of Reclamation of Strip-Mined Lands"

Kathy Tonnessen
Energy and Resources Group
University of California, Berkeley

Surface Mining Control and Reclamation Act of 1977

It has been widely acknowledged that surface mining of coal has disruptive effects both on humans and on the environment. Yet until 1977 there existed no Federal statute regulating strip-mining reclamation practices. Many states had adopted regulations to internalize some of the environmental costs of coal mining operations, but the enforcement provisions of state regulations were often weak and ineffectual.

Environmentalists proposed a Federal law, and in both 1974 and 1975, Congress passed strip-mining bills. But President Ford vetoed them, claiming that these measures would cut coal production by 187 million tons per year and cost 40,000 jobs. Not until 1977 did President Carter sign into law comprehensive legislation. The Surface Mining Control and Reclamation Act of 1977 (SMCRA) was designed to protect both society and the environment from the adverse effects of surface mining operations, to prevent mining where proper reclamation is not feasible, and to require that reclamation be properly and promptly completed.

The Office of Surface Mining and Enforcement (OSM) was created immediately within the Department of Interior to set standards and coordinate a Federal program. Enforcement officials and inspectors within OSM serve as backup in a system which emphasizes state implementation of OSM regulations or more stringent state ones. The primary objective of these regulations is to insure that coal is mined in an environmentally acceptable manner, particularly in light of the Administration's recent policy to increase the level of coal production and use by 1985.

The inadequacy of the public comment procedures and the lack of scientific and technical input during the actual drafting of the regulations are noted as principal obstacles to effective drafting of regulations.

Two issues are particularly important to consider in any discussion of Federal decisionmaking such as that related to SMCRA: first, the type and quality of information on environmental effects of surface mining available to decisionmakers; and second, the extent to which pivotal environmental tradeoffs -- using integrated assessment techniques -- were considered in the regulatory process.

Regulatory decisions depend heavily on the technical information available to the decisionmaker. Accurate and adequate information is essential in assessing the impact of public policy on the environment. Environmental tradeoffs -- sacrificing of one environmental amenity for another -- can only be intelligently evaluated in a situation where both good information and effective analysis tools are available.

The creation of a new regulatory agency, the OSM, and its cooperation with EPA in promulgating standards for reclamation of strip-mined lands, provided an opportunity for use of integrated assessment methods in the formulation of standards to be applied across all states. The need for precise yet flexible regulations was obvious.

No Comprehensive Integrated Analysis Was Made

In the drafting of SMCRA, other technologies for mining coal, such as deep mining, are not considered directly or in any systematic manner in order to devise some indices of impact which could be compared

across technologies. Some cross-media impacts were considered. Effects of land use in mining activities are seen as having some impact on water resources, in the form of stream sedimentation, contamination of subsurface aquifers and surface-water acidification due to runoff from spoil piles and exposed highwalls. Alternatives to use of coal as fuel for the generation of electricity are not considered implicitly or explicitly by the legislators or the regulators. Rather, the assumption that coal should be mined, but in an environmentally safe manner, is the basis upon which the regulations were promulgated.

The number of significant tradeoffs which would have to be considered in order to arrive at the best regulatory program for control of the environmental impacts of surface mining is staggering. Integrated assessment could have been used to consider the more important tradeoffs comprehensively. It is obvious that formal integrated assessment techniques (such as the use of an integrated model) were not used in the formulation of the surface mining control and reclamation regulations. At present, there exists no mechanism, model, or quantitative tool which would allow for such a consideration of all the tradeoffs involved in the issue of environmental protection of strip-mined lands. It is not surprising then that Congress and the OSM opted for an ad hoc approach to standard setting.

Politics Outweighs Technical Factors

Technical information on slope restriction, sedimentation and revegetation was available to decision-makers when the SMCRA and surface mining regulations were formulated. It is asserted that "best engineering judgment" was used to arrive at certain land-use standards. However, in view of the interest groups having a stake in the outcome of the regulatory process, it is reasonable to assume that the precise regulations were the result of influence exerted by these various groups: state and local governments, environmentalists and industry -- among many others. Solidarity within the coal industry, between both the underground and the surface mine operators, particularly in the Appalachian region, resulted in a united front in opposing stringent controls on surface mining activities.

Environmentalists had a stake in the formulation of the most stringent set of regulations possible. State officials who were concerned with their own strip-mining policy supported the regulatory program which emerged -- one which emphasizes state control and implementation of regulations which may be more stringent than the Federal regulations. The Federal regulatory program could prove a boon to state regulatory programs by supplying a vital support for state regulatory power.

DISCUSSION OF TONNESSEN PAPER

Robert Curry, University of Montana

Curry found this to be a good and comprehensive paper dealing with current data and developing ideas. It correctly identifies areas in which integrated assessment (IA) methods were used. The setting of surface mining regulations was an enormously difficult task, due to the breadth of the subject, and the fact that the OSM is a new agency, largely staffed with retreads from other agencies. In addition, the final form of surface mining regulations has important political ramifications, so the decisionmaking process had a considerable amount of political input.

The legislative and regulatory histories of the OSM and surface mining regulations are essentially correct; however, they do not include a consideration of the temporal constraints that affected the regulatory process. New drafts of proposed regulations were assembled so quickly that often, by the time public comment and feedback were received on one draft, two more drafts had already been released. Information flow was also a crucial constraint because the draft regulations were written by attorneys who often had difficulty understanding technical issues. These constraints made comprehensive IA nearly impossible.

Curry felt that the section on information sources is the key to the paper. Tonnessen was misled, as intended by the OSM, into thinking that technical data bases were used in the development of regulations. In fact, the lawyers working for the agency merely padded the Federal Register with data indiscriminately, in order to set up a defense for future litigation. A good example is the use of the terms "hydrologic balance" and "hydrologic equilibrium", both of which were written into the law, although they are not generally understood. Tonnessen used the NAS/NRC report on the potential for rehabilitation of Western surface mined lands, and the National Coal Policy Project (NCP) as examples of IA; however, she missed several subsequent reports refuting some of the simplistic and inaccurate conclusions reached in these reports, such as the 10 inch annual precipitation cut-off.

Curry suggested that Tonnessen missed the most important tradeoff of all -- time. This was brought out in the NCP. Surface mining regulations must deal with the tradeoffs between short-term gains vs. long-term productivity, or short-term rehabilitation ("greening") vs. long-term stability. In addition, there are crucial tradeoffs to be considered -- East vs. West, surface vs. underground, high sulfur vs. low sulfur. These issues are affected by several types of environmental regulations, including BACT, mining regulations, etc.

Jerome Harper, Argonne National Laboratory

Harper explained that the Surface Mining Control and Reclamation Act (SMCRA) of 1977 gave a mandate for a novel form of governmental regulation of business. It stipulated that the national need for a guaranteed coal supply and for environmental protection were to be considered together, and it required implicitly that the tradeoff between mineral resource extraction and land productivity be considered. Although nationally only about 11% of strippable coal reserves are under prime farmland, in some Midwestern states as much as 45% is.

Eventually, OSM regulations will cover both underground and surface mining of coal. Shifts in the ratio of surface to underground mining will cause impacts to be transferred both across media and regionally. The East-West tradeoff is very important, and very difficult.

For effective regulation, IA is necessary. The first step in the process should be to fill gaps in the major data bases. A matrix approach for IA can be used. Policy aspects, including temporal constraints and interagency conflicts, must also be considered in assessing the potential problems of regulation.

General Discussion

The OSM's job of surface mining regulation is exceedingly difficult for several reasons. Cross-media tradeoffs will be an inevitable result of any set of regulations (e.g., air vs. water), and this imposes the institutional complexity of crossing agency boundaries. The regional tradeoff issues are also complicated by the presence of these cross-media impacts. In addition, policy decisions that are not under the control of OSM, such as regulations relating to the application of BACT, will influence where coal is mined and burned.

There seems to be little cooperation between agencies that share common concerns. Decisions that are made on the basis of IA methods by the OSM could be subverted by actions taken by other agencies. It was suggested that a further legislative mandate might be necessary in order to coordinate research and policy development.

"A Review of EPA's Evaluation of the Environmental Impacts of New Source Performance Standards for Fossil-Fuel Power Plants"

Veronica Kun
Energy and Resources
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The Environmental Protection Agency's performance in the evaluation of environmental impacts in connection with its stationary source air pollution control programs is analyzed. A case study approach is used to highlight the standard-setting process and to identify the ways in which tradeoffs among environmental impacts have been analyzed and evaluated. The New Source Performance Standards (NSPS) for sulfur-oxide (SO_x) emissions were chosen for study because of the wealth of available information and documentation on this particular problem.

General Framework of the Clean Air Act As It Applies to Stationary Source Control

The Clean Air Act of 1970 mandated EPA to identify major stationary sources of air pollution and to set performance standards for certain classes of facilities. These specific emissions limitations were to be based on certification by the Administrator of the Agency of the "best adequately demonstrated control technology", taking account of economic costs. The Act did not stipulate any requirement for consideration of environmental impacts in media other than air.

The 1977 Amendments to the Clean Air Act defined the "best adequately demonstrated control technology" as a system of continuous emission reduction. These amendments explicitly mandate consideration by the Administrator of the effects of any proposed standards on energy consumption during routine operations at power plants. The amendments also call for consideration of environmental impacts in media other than air. They do not establish specific policies or guidelines for valuing or balancing the tradeoffs among these impacts.

Promulgation of New Source Performance Standards: Agency Procedures

Analysis of technologies designed to reduce sulfur-oxide emissions from power plants have indicated that sulfur-control activities will displace environmental impacts to other media and may increase the severity of some of the impacts. The tradeoffs for reduced atmospheric emissions of sulfur-oxides include: (1) land and water-quality impacts from increased volumes of sulfuric sludge; (2) environmental degradation from increased procurement and use of fuel; (3) increased requirements for scrubbing materials; and (4) increased water consumption in power plant operations. The absolute and relative importance of these impacts varies with the location of the facility, the control technology employed, and the susceptibility of the impact to mitigation.

Voluntary environmental impact statements were prepared for both the initiation and revision of the SO_x NSPS. The main purpose of these analyses was to identify the primary and secondary impacts of proposed regulations and standards. Since 1974, the Agency has failed to develop a systematic and comprehensive procedure for determining which impacts will be considered germane. Partly as a result of this defect in the assessment process, the Agency has been unable to implement the resulting analyses in a uniform and consistent fashion.

The background documents prepared with the original NSPS for fossil-fired power plants include information concerning the technical, environmental and economic bases for standard-setting. The only non-air impact acknowledged in these background documents was the problem of sulfur-sludge disposal. There is

no discussion of cross-media tradeoffs or criteria for evaluating the implications of these tradeoffs on the process of setting standards.

Since 1971, EPA's Assessment Program for evaluation of the sulfur-oxide standards has focused on the problems of sludge disposal and on the fuel-use impacts of the proposed standards. Integrated assessment of the environmental impacts of emission-control standards has been hindered by several factors. The analyses have considered only the choice between the standards as proposed by EPA or no standards at all. No attempt has been made to optimize the standards by explicitly balancing the value of the tradeoffs among potential environmental impacts. Only human health effects have been considered in the calculus of environmental costs. Other consequences of environmental insults have been largely ignored.

The Agency's interest in the non-air impacts of sulfur-oxide emissions control appears to have been constrained by the statutory limits of its jurisdiction. The background documents for the revised NSPS identify technologies for the mitigation of the environmental impacts of sulfur-sludge disposal. Because the EPA has no specific mandate to set standards for such activities, it did not closely evaluate their effects.

Analysis

The Agency's response to the Courts in *Essex v. Ruckelshaus* illustrates its difficulties in attempting to grapple with the problem of balancing the tradeoffs among environmental impacts. EPA has continued to evaluate and document technologies for sulfur-oxide-emission control. For the most part, the studies have been very conventional, with attention focused narrowly on sludge-disposal and fuel-use impacts. One study evaluated the availability of certain scrubbing materials. No new tools for integrated assessment have been developed.

The failure of background documents for the revised NSPS to utilize or reference earlier studies suggests a lack of coordination at EPA. Barriers to the performance of integrated assessments and to the efficient utilization of the information generated in conventional environmental impact analyses seem to result from conflicts in the bureaucratic structure of the Agency.

Three levels of environmental analysis are identified as components of integrated assessment. At the first level of analysis, the magnitude of anticipated environmental insults are estimated. Although the Agency's performance at this level has been adequate, the utility and comparability of the resulting analyses has been constrained by the lack of uniform criteria determining the limits of the analyses. No method more sophisticated than a checklist has been developed by the Agency to assure comprehensiveness in the identification of relevant impacts.

At the second level of analysis, the consequences of anticipated environmental insults must be determined. For this level of analysis, the Agency's performance has been near the state-of-the-art. The greatest difficulties for this task have been encountered when (1) the consequences of the anticipated insult are largely site-specific, (2) when the impact generates a risk whose magnitude involves a high degree of uncertainty, (3) when the biological, physical or epidemiological links to consequences are poorly understood, or (4) when technological mitigation measures exist but the Agency has no jurisdiction over their implementation.

The third level of analysis involves the valuation of environmental impacts. Successful performance of this task seems impossible under the framework of conventional assessment procedures. Rather than attempting to break new ground, the Agency has largely avoided balancing the impacts of tradeoffs among environmental effects in different media.

DISCUSSION OF KUN PAPER

Stanley Greenfield, Flow Resources Inc.

Greenfield felt that in too many cases, data just do not exist for performing a meaningful integrated assessment (IA). Existing ambient air standards were set by Congress, and the EPA's job was to design a strategy for implementing those standards.

In regards to reducing emissions from a source type, the original new source performance standards (NSPS) never looked at costs. Rather, they required emission reductions that were attainable using the best available technology. Present efforts to set NSPS's have begun to consider costs.

In considering total impacts, there is a big problem in setting uniform standards. Uniform standards are insensitive to regional differences, and do not address the issue of whose concept of the environment is to be protected.

Weston Vivian, University of Michigan

Vivian felt that the paper outlined the history of the regulatory process well, considering that documentation was based on the public record. Congress gave some guidance to the EPA for setting NSPS standards. Most of the key issues were addressed, and the high costs of compliance were appreciated. The divisional structure (along media lines) of the EPA hindered the assessment process, and no means was suggested to the EPA for performing IA.

EPA chief Costle was forced by the courts to act by a specified date, so the NSPS's were formulated under severe time constraints. Strict standards were imposed with the understanding that during future adjustments, the regulations would be more easily eased than tightened. The EPA would have done IA, but didn't know how.

Vivian gave a very political interpretation of the EPA's role and position in the setting of NSPS standards. The EPA's mission is to regulate, and its natural constituency is environmentalists.

Vivian felt that IA has several difficulties, including estimating labor impacts and assessing social tradeoffs. A standard can be thought of as an educational tool, with the numbers open to manipulation and adjustment.

General Discussion

It was pointed out that there is probably a 10:1 ratio of unpublished to published reports in the EPA. This helps to account for the lack of comprehensive documentation of the EPA's decisionmaking process.

Constant internal conflict within the EPA between the different divisions hinders the IA process. Organization along media lines was a tactic that EPA chief Ruckelshaus used in order to gain control of the agency, and its legacy is difficult to work with in doing IA.

The EPA has a mandate to protect the public health and welfare. Welfare is difficult to define, and we are so far away from protecting the public health that why worry?

"Pursuing the Search for Comparability: A Case Study of Mobile Sources of Air Pollution"

Michael M. Simpson
Energy and Resources Group
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What's Happened So Far?

For our purposes, the issue of Federal policy regarding air pollution arose in 1950, when studies at the California Institute of Technology first associated automobile emissions with smog in the Los Angeles Basin. Shortly thereafter, the Los Angeles Air Pollution Control District began encouraging the automobile companies and the state government to take corrective action.

Manufacturers denied that automobile emissions were a problem, and letters of the time seem painfully blind to us now. The Automobile Manufacturers Association, nonetheless, set up a study group to conduct research and exchange technical information. In 1954 they reached a cross-licensing agreement among themselves for air pollution control equipment.

The first Federal legislation on air pollution came in 1955 with PL 84-159, which located responsibility in the Department of Health, Education and Welfare (HEW). This law provided for Federally sponsored research but did not grant the Federal Government any enforcement powers. The Public Health Service, which assumed administration of the program, opposed Federal enforcement powers and insisted that the responsibility resided with state governments.

The Clean Air Act of December of 1963 (PL 88-206) established the earliest Federal enforcement powers; it authorized the Federal Government to convene interstate pollution abatement conferences, and in some cases, to initiate Federal suits to force reduction of emissions. It also provided for Federal grants to stimulate research and to increase state control activity, and it specifically mentioned the need for further attention to automotive exhaust. A second title to the Act was passed in 1965 authorizing HEW to set emissions standards for automobiles beginning with the 1968 model year. A year later, HEW announced a 1968 standard roughly the same as had come into effect in California in 1966.

The National Emissions Standards Act was enacted in December 1970 as Title II of the Clean Air Act. It established emissions standards for hydrocarbons, and carbon monoxide for new cars in 1975, and an additional standard for oxides of nitrogen to be met in 1976. These standards constitute a 90 percent reduction below the 1970 levels of the CO and HC and the 1971 level of NO_x. The Act also enables EPA to carry out certification tests to confirm compliance, to conduct research to establish fuel regulations, to require and enforce warranties from auto manufacturers, and to certify and subsidize on-the-road inspection and testing programs. For violations of the emissions standards, such as marketing vehicles not certified, the Act imposes a fine of \$10,000 per vehicle. This is the only enforcement device; in effect, it stops the production of model lines not certified.

But there is ambiguity about the intention of the Act in establishing a specific level of reduction in auto emissions. From one viewpoint, the legislation can be understood as an effort by Congress to exert pressure on the obvious political targets by means of legislation. The Congress was moved to do something forceful on behalf of the environment; and the auto manufacturers, indisputably responsible and politically vulnerable, were an obvious target. The Act clearly got tough with them, by means of stringent standards, tight deadlines, provisions requiring them to supply data, and language requiring a good faith effort to comply regardless of the technical difficulties involved.

Congress specified the use of emissions standards rather than emission charges or subsidies, which have different enforcement requirements. Some thought seems to have been given to the macroeconomic effects

of the standards and to possible increases in fuel consumption produced by the use of emissions-control technologies. Less consideration seems to have been given to the resource requirements for catalytic converters, to the tradeoffs between various emissions-control technologies and automobile safety, and to the problem of sulfuric acid emissions from catalytic converters.

In future efforts to clean the air, keeping means separate from ends, improving and using models and data, and striving to examine cross-effects and costs would be desirable.

Control Strategies Must Be Feasible, Efficient, and Equitable

In general, control strategies must meet the criteria of feasibility, efficiency, and equity. Feasibility depends on both technological factors and legal and political factors. Efficiency implies a balancing of costs and benefits. Two types of costs are relevant: the cost to the emitter of achieving the required emission reduction, and the cost to the control authority of implementing, monitoring, and enforcing the control policy. The former cost is determined largely by technological factors; the latter is dependent principally upon legal and administrative considerations, although technological development in the field of inspection facilities may also be decisive here.

The efficient level of pollution at any point in time depends on the technological state-of-the-art. The efficient quantity of urban air and the efficient set of strategies to achieve this air quality may vary from one urban airshed to another.

Equity pertains to the relationship between who derives the benefit to who pays the cost. Any control strategy which is chosen should be compatible with conventionally accepted notions of fairness. It is difficult to arrive at a generally agreed upon equity criterion which approaches any degree of precision.

Different strategies can lead to quite different distributions of benefits and costs. An obvious example is charges versus subsidies, but there are more subtle differences among other strategies as well. For example, a policy which controls mainly new cars will place greater burdens on high-income classes than one of controlling used cars. Any strategy which is efficient but leads to a regressive distribution should perhaps be supplemented by another program which would offset the distribution deficiencies.

Integrated Assessment Tools Did Not Exist

In the early days of controlling mobile sources of air pollution, integrated assessment tools were not used, primarily because none existed. Some non-integrative tools did exist, for analyzing such specific topics as the health effects or macroeconomic effects of air pollution control, but these went largely unused. In time, their sophistication and/or numbers increased to the point where the standard-setters could no longer ignore them, and some of these specific studies were used to help set air pollution control standards. Their main deficiency is that they are non-integrative; they do not deal with the problem of cross effects. It is our hope that integrated assessment methods will be able to equitably and efficiently handle such tradeoffs. In the event that development of satisfactory integrated assessment methods proves impossible, we make a two-part recommendation:

Data should be presented in a uniform fashion. Federal auto emission standards have been uniformly reported in grams per mile for some years, and other data should be subject to standardized presentation formats. The best forms should be decided by reasonable debate. The benefits of easier and potentially more accurate comparisons, essential to equitable and efficient decisionmaking, should surpass the possible complaints of difficulty of transition.

The public should be more intimately and directly involved in the decisionmaking process. Presentation of data in a uniform fashion should help the public decide issues of comparability.

These can help in the future efforts of cleaning the air and improving the human condition: keeping ends separate from means; improving, using, and standardizing models and data; and striving to examine cross-effects and costs, using integrated assessment tools when possible and public decisionmaking at other times.

DISCUSSION OF SIMPSON PAPER

Eric Stork, Purdue University

Stork found the history of the control of mobile sources of air pollution to be incomplete, with instances of incorrect data and incorrect interpretations. The paper argues strongly for the use of economic incentives, but he noted that the Congress considered and rejected such techniques because they would turn out to be an administrative nightmare.

The paper is critical of the narrow focus taken by the EPA, without giving reasons. Stork wondered what harm the narrow approach had caused, and whether a narrow approach was necessarily bad. Stork complained that the paper was full of motherhood dicta, and did not fully consider the political nature of the regulatory process.

In Stork's view, the essence of the problem lies in providing regulators with the proper set of signals and goals. Regulators currently have no incentive to concern themselves with compliance costs, and the Congress gave the EPA an impossible mission. Reasonable goals have to be defined. One approach that might help would be a regulatory budget system, which could be an effective "meat-axe" for effecting institutional change. The EPA has already given up cost/benefit analysis in favor of cost effectiveness analysis.

James Krier, Stanford University Law School

Krier began by stating that he both agreed and disagreed with Stork and Simpson. It is impossible to tell what the true intent of the Congress was in 1970, and indeed, it is impossible to tell exactly what has been accomplished since then. There is no correct version of history. A person on the outside has a different view than a person on the inside. Krier felt that, from the perspective of an outsider, Simpson's version of the history was accurate enough.

Krier then noted his disagreements with several points of the analysis. He maintained that there is a great danger in trying to quantify effects such as air pollution damages or value of human lives, effects that are too resistant to quantification to be meaningfully valued in dollar terms. When people consider these things, they describe the effects, rather than count them.

Simpson's paper was also deficient, in Krier's opinion, in leaving out considerations of distributional equity, including both geographic and temporal variations. Environmental goals cannot be valued without knowing the distributive implications of various control strategies.

Krier had several comments to make about integrated assessment (IA) in general. He felt that even narrow assessments are so difficult that it would be better to attempt to do a good narrow assessment that includes cost-minimizing, equity-satisfying strategies, before attempting a broad IA. There is a danger in promoting IA if it cannot be pulled off, in that inaction could be the result of protracted deliberations in the IA process. An important problem in the IA process is knowing how to bound the problem and when to apply it. Economists' concepts of "second best" and engineers' concepts in bridge building may be useful in bounding IA.

In the short-term, it is more important to concentrate on narrow problems, such as fair and efficient motor vehicle standards, than to worry about broad IA. There are dangers in such a narrow strategy, but at least the job can be done.

General Discussion

Ultimately, it is up to Congress and the courts to make final decisions on environmental policies. Reasoned argument given to people both inside and outside of Congress can be very effective in planting seeds of concern. Each problem that arises is fairly unique, so the decisionmaking process is an art, relying a great deal on insight and imagination. There can be a technology to the art, however, telling people what things are important to think about. Social intuition should be incorporated into the decisionmaking process.

IV. SYNOPSIS OF ROUND-TABLE DISCUSSIONS

ROUND-TABLE DISCUSSION 1:

BETTER MECHANISMS FOR INTEGRATED ASSESSMENT:
ARE THEY NEEDED? WHAT WOULD THEY LOOK LIKE?

Moderator: Peter House

Framework for Discussion (House)

Two basic points of view were exposed during the conference's first day. First: If better methods of integrated assessment had been available to decisionmakers, the decisionmaking process could have been done more efficiently, with different results. Second: If outsiders knew what really went on behind closed doors, then they would not question the process. Integrated assessment can mean a lot of things to a lot of people at different times. It can be done at any level of government and can range from general standard setting to site-specific Environmental Impact Statements. Let's focus on integrated assessment at the Federal level, with a top-down perspective, examining rulemaking and standard-setting guidelines. Let's discuss four integrated assessment issues:

1. How is it done now?
2. How well do these methods work (and what does "work" mean)?
3. What improvements could be made?
4. Why is it not already done?

General Discussion

It was generally agreed that, although formal and deliberate use of integrated economic-environmental assessment models is relatively new to policy analysis, integrated assessment has always been done by regulatory agencies. Integrated assessment is currently portioned out to different agencies, to different departments within agencies, and between different social concerns (urban impact analysis, labor impact analysis, health impact analysis, etc.). The integrative part of the policy-formulation process is accomplished through a sort of marketplace interplay within the government.

It was pointed out that the Environmental Impact Statement (EIS), as it was originally conceived, was to be a method of integrated assessment. Lack of a strong lead agency, however, has impeded the EIS process. Each agency feels the need to protect its own turf and court its natural constituency, and these concerns can interfere with the integrated assessment process. In addition, agencies are primarily concerned with real and budgetary costs, rather than social and economic costs, and there is no provision in cost-benefit analysis to insure that groups bearing a disproportionate share of the costs will be compensated. Often, agencies merely go through the motions of integrated assessment, in order to justify their decisions to their constituencies.

A question was raised concerning the types of approaches to environmental assessment that are desired by decisionmakers. It was generally agreed that decisionmakers require hard analytical data to back up their decisions, and simple-to-understand analyses that hang together under attack. Several of the participants pointed out, however, that data can be produced to support all sides of a controversy, and that often assessment methods are used after a decision has been made in order to support that decision.

Many of the decisionmakers and former decisionmakers at the meeting expressed satisfaction with past uses of integrated assessment in the policy formulation process. The need for constant compromise may impede the process; however, a clear delineation of the uncertainties can help to insure that spurious justifications are not used for making policy.

Regarding the allocation of major research efforts among the various categories of research types (basic research, development of models and data bases, theoretical decisionmaking models, etc.), nearly all of the participants agreed that basic research, both in the environmental sciences and economics, would always be cost effective. Basic research is necessary to form the basis upon which integrated assessment can be performed. Opinions on the necessity for improving some of the large models (e.g., SEAS, MERES, etc.) were mixed, and many expressed disappointment with the past performance and high costs of the large data bases. Good data, it was agreed, are crucial for any effective environmental program, regardless of whether IA methods are used as the core analytical tools.

ROUND-TABLE DISCUSSION 2:

CONSTRAINTS ON IMPLEMENTING BETTER MECHANISMS FOR INTEGRATED ASSESSMENT: LEGAL, POLITICAL, INSTITUTIONAL

Moderator: Joseph Coleman

Framework for Discussion (Coleman)

This session will focus on the following four issues concerning the setting of regulations for new energy technologies:

1. How should standards be set for energy technologies?
2. Why should the process be different than at present?
3. What are the alternatives (for example, net pollution analysis)?
4. What are the implementation problems?

General Discussion

The second round-table session began with a discussion of how to set new standards for energy technologies. Four basic approaches to standard setting were suggested: (1) Experiment with standards in order to find the most effective ways to regulate. (2) Use cost-benefit analysis as the basis for standard-setting. (3) Start with available process-engineering data and impact statements from major R&D contractors, and work from there. (4) Avoid the possibilities of particularly undesirable risks, such as risks of an irreversible nature or risks of catastrophic events.

A general consensus seemed to emerge that new and emerging technologies could and should be treated differently by regulators than conventional technologies. Standards for new technologies could serve to discourage or encourage their further development and implementation. In addition, early use of integrated assessment methods could facilitate the concurrent development of abatement procedures in order to mitigate the harmful effects of a new technology. It was also pointed out that certain regulations or performance standards could be selectively relaxed in the case of new technologies in order to encourage innovation.

Some of the conference participants expressed the view that new-technology development is hampered by an uncertain and rapidly changing regulatory environment. Controls have to be designed commensurate with existing regulations; however, it is important to design-in flexibility in order to be able to adapt to changing regulations and standards.

It was suggested that one possible alternative to relative risk analysis would be to apply net pollution analysis (NPA) as a basis for setting standards. Many participants expressed strong reservations about the efficacy of using NPA, owing to the methodological shortcomings of the technique. NPA is just another environmental indexing method and, as such, is useless without some sort of common measure, such as damage functions, dose-response relationships, or other measures of impacts on human well-being. A laundry list approach has the potential to characterize environmental effects without indexing them, and may be more useful to decisionmakers. Regional differences are also important, and deserve emphasis.

With respect to standard-setting in the face of persistent uncertainties, the view was expressed that, in practice, only those impacts that are already known can be relevant to decisionmakers. Highly uncertain or poorly characterized effects have little chance of being incorporated into standards and regulations. The simplest way of dealing with uncertainties is to ignore them, and simply work on the basis of what is known. A more dynamic approach is to make preliminary judgments, but to design flexibility into regulations so that new information can be easily used to update and improve standards. The EPA, for example, has used this approach by deliberately setting standards that were too stringent, so that subsequent readjustments would not weaken them too much.

ROUND-TABLE DISCUSSION 3:

AGENDA FOR FURTHER RESEARCH

Moderator: John Holdren

Framework for Discussion (Holdren)

In planning the next stage of our work, two interrelated issues are central: What are the most important questions to address? What kinds of experience and/or intellectual resources are needed to answer them, and are these resources available to the study group?

A set of candidate questions is provided at the end of the workshop paper by Holdren, Harte, and Tonnessen. Rephrasing somewhat, they are as follows:

1. How important is what is known about environmental problems compared to what is unknown or imperfectly known, from the standpoint of illuminating choices facing decisionmakers?
2. How resistant to being closed is the gap between what is known and what needs to be known if decisions are to be sensible? In other words, what is the velocity of the "boundary" of knowledge in areas of importance to decisionmaking, and how susceptible is this velocity to being increased by the application of resources?
3. Are there analytic and decisionmaking strategies that could lead to better decisions in the face of resistant gaps in knowledge? What are they?
4. How should financial and intellectual resources be allocated among:
 - (a) relevant basic science (economics, environmental science)
 - (b) improving data bases and integrated models

- (c) improving decisionmaking in the face of information gaps and uncertainties
- (d) producing good examples of integrated assessments to serve as models and inspirations for further work.

The answers to questions 1 and 2 characterize the problem. The answers to questions 3 and 4 tell one how to proceed.

General Discussion

The view was expressed and agreed to that the next phase of the work should not simply be a more detailed examination of large-scale models. More useful would be illuminating the relation between the nature and quality of information available to decisionmakers and the decisions made. Questions related to this topic are:

1. Can one find specific cases where decisions would have been different if better information had been available?
2. Would consideration of more variables, rather than better data on the variables considered, have changed any decisions?
3. Would decisions have been made earlier if information had been available earlier?

Various and often contrasting opinions were expressed on what would be revealed by research on these questions.

Some of those present suggested that information is rarely the determining factor in policy decisions, and that the use of formal models and data bases is often post hoc, to justify decisions already made rather than to guide decisionmaking. Nevertheless, some of those present mentioned decisions that they thought could have and would have been made differently if information that later became available had been available to the decisionmaker in time to be used.

There was considerable discussion about the problem of selecting the "right" variables for presentation to policy makers. Too many variables become confusing, or simply wasteful of effort; too few may fail to illuminate the crucial issues. It was agreed that the selection of the proper variables is at least partly an art, but it was suggested also that the "art" can be studied, taught, and learned to improve the average quality with which it is practiced.

With respect to the timing of decisions, the view was expressed that a decisionmaker never makes a decision until absolutely necessary, which of course increases the chance of getting better information. This behavior is due to the fact that, to the decisionmaker, the cost of delay (until a bureaucratically or politically imposed deadline) is low, even if the cost to others is high. One response was that this situation calls for finding ways to internalize into the decisionmaker's balance sheet the high external costs of delay, where these exist. It was also suggested that deciding rationally when a policy decision should be made requires knowing how rapidly new information is becoming available. If the boundary of the body of relevant knowledge is moving rapidly, costs of a short delay in making a decision may be more than offset by the improvement of the decision (or confidence in it) made possible by the extra information. But if there is no realistic prospect of better information on any time scale of decision-making interest, delaying the decision on grounds of uncertainty is inappropriate.

It was suggested and generally agreed to that three central problems in environmental policy making are (1) comparability (apples and oranges), (2) various forms of double-counting of costs and benefits, and (3) difficulties arising from the distribution of costs and benefits across various groups of people, including future generations. Although one generally thinks of the political process as the appropriate forum for resolving distributional issues, it was suggested that politics is the worst arena for taking

future generations into account because of the short time perspective characteristic of politics. All of these problems are suitable focuses for continued research, but they must be pursued in the context of specific technologies and specific choices facing policy makers if the results are to have much impact.

V. SOME CONCLUDING OBSERVATIONS

Integrated Assessment An Art Not Rigorously Practiced

No Federal agency practices integrated assessment, broadly or consistently. At best, sporadically. The workshop left no doubt of that. Not even in the narrowly technical sense of making sure that all factors that might impact an energy technology are considered. When integrated assessment is widened to include the political pressures and time constraints of the top-level administrators and decisionmakers, the improbability of its being carried out broadly and consistently increases substantially.

But it's not that easy. Practically all participants admit that the widest possible range of impacts have to be considered, and that administrators do try to consider them. Which impacts and the extent to which attempts should be made to interrelate them, to determine synergistic, genuinely integrative effects, is where personal and professional opinions split. Integrated assessment, as practiced, is an art, however scientific in concept, and the opinions and expertise of experts and decisionmakers will determine how it is practiced.

Each Agency Has To Go Its Own Way

Under President Carter's urging, the regulatory budget approach to regulation is being taken -- determining what is the total cost of a regulatory program. Having assembled total costs, the next step of an integrated cost-benefit analysis becomes less remote. Or even less demanding, determining the cost efficiency of various regulatory tradeoffs, and comparing them with at least a rough approximation of the impact benefits or dysbenefits.

Distributional equity -- groups of people are differentially affected over space and time -- has to be addressed, not only in the analysis, but in the institutional projection of remedying inequities.

What constitutes integrated assessment for various agencies at various times differs in practice, and probably in concept. Mission of each determines what impacts must be taken into consideration, or at least which should be given priority. But the requirement for each agency to construct its own framework for integrated assessment is obvious. Many of the tools, and much of the data, are there. New tools, new data will always be available. Requirements will always be shifting. Some may be impossible to meet. But the overall requirement for integrated assessment becomes increasingly more demanding.

Integrated assessment won't replace the decisionmaker, but it might help assure his less frequent replacement, as his decisions are more broadly based -- before the fact where possible, or sequentially adjusted where ongoing experience shapes responses to hot situations dealing with volatile issues.

How Are Integrated Assessment Procedures To Be Implemented?

To go beyond speculation, however, requires a detailed analysis and evaluation of the integrated assessment process. Consequently, you must examine systematically the necessary sequence of activities. In this context, a legitimate question is whether each instance of implementation will be unique, thus making efforts to deal with implementation, other than on a case-by-case basis, futile. Implementation should be within the scope of technology planning, and they should inform technology design. Why? Because the payoff from Federal R&D expenditures is not realized at the point of technical feasibility, but at the point of user adoption.

A final question is, how does one institutionalize a process like integrated assessment and make it work? To progress beyond the usual Federal bureaucratic WAG (wild-assed guess) assessment procedures.

Fairly standard methods for instituting a new directive can be found in any text on public administration. The secret of implementing integrated assessment is realizing that, although it may appear straightforward, it represents a fairly fundamental change in the reward structure of Federal agencies. Good managers are presently seen as technically competent people in the field(s) where they made decisions. Decisionmakers may be technical people themselves, attending professional meetings, giving papers, and publishing articles and books. They are trained problem solvers and have little trouble evaluating the technical worth of projects. Many, however, are not interested in or qualified to assess effective technology.

To change the reward structure of policy and planning with agencies involves an attitudinal shift. Most people would agree to a reasonable, clearly defined, objective function if the shift were recognized by their superiors -- the decisionmakers -- and used. This means integrated assessment will have to be supported by people in positions of authority. If all levels of administration endorsed it, each level would support the one below, establishing a whole new philosophy of management responsibility. No need cause for despair. Although there is some cause for despair about the integrated assessment postulations we have presented, the practical utility of the results are not startling. No practicing policy analyst or experienced decisionmaker ever takes as gospel any assessment, regardless of how derived. Our institutional structures are designed so that major decisions can be revisited and revised as more information becomes available or as experience changes the perceptions and goals. Finding out, through comprehensive integrated assessment, that we are not very sure of what will really happen if a particular policy choice is made, is not news to the experienced. Policy makers who have a preconceived notion learn that it is their peril to ignore the results of integrated assessment, however counter-intuitive.

VI. FULL TEXTS OF BACKGROUND PAPERS AND WRITTEN RESPONSES OF DISCUSSANTS

COMMENTS ON ANTHONY FISHER'S
"TOOLS FOR MEASURING POLLUTION DAMAGE COSTS: A CRITICAL REVIEW"

Prepared for:

Workshop: Integrated Assessment for Environmental Standards
Berkeley, California
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1.0 INTRODUCTION

When I am asked to be a critical reviewer of a "Critical Review", I try to put myself into the role of the author of that Review, and ask:

- o Would I have made a similar selection of issues, topics and scope?
- o Given the selection, would I have approached each topic (about) the same way?

If the author selects a very different set of issues and topics, as to some extent has happened in this case, I take the liberty of addressing some of these issues, myself. I do this in the first part of this paper less to be critical of the author than to seek to open the discussion to issues and discussions I believe are worthwhile to pursue. Furthermore, I believe "integrated assessment" to be what integrated assessors (i.a.) do; therefore, as one of the outlying members of this growing fraternity, I take advantage to recommend the following topics for inclusion within the i.a. field.

In the section following that, I address issues raised by Fisher's paper, itself.

2.0 SCOPE AND CONTENT: WHAT ECONOMIC TOOLS ARE USEFUL?

I have presumed that the topic originally proposed for Fisher's paper was that called for in John Holdren's paper* (p. 10), to "review economic tools relevant to integrated assessment".

This is an immense topic so I sympathize with Fisher's need to narrow the subject to manageable size. Fisher has chosen to review "some tools for measuring pollution damage costs". I am disappointed for several reasons:

* "Integrated Assessment for Environmental Standards: An Introduction to the Study", October 1, 1978.

- o For "economics" to be especially helpful, it needs to make considerable inroads into benefit and risk, as well as improved cost assessment;
- o What Fisher has chosen to cover here has already been discussed in similar fashion in other places*;
- o Fisher's other work (e.g., Arrow and Fisher, "Environmental Preservation, Uncertainty, and Irreversibility"**) deals extensively with considerably more difficult -- but at least equally important topics for integrated assessment, such as (a) risk and uncertainty, and (b) decision-making under conditions of incomplete and uncertain data.***

My complaint is more that I wish Fisher had dealt with some of the more difficult technical issues, although I grant that some of these are in such an embryonic stage that the economist's contribution has not yet been very significant. I also realize that Fisher has attempted to maintain this paper at the layman level; this, unfortunately, is inconsistent with the objective of "sizing up the state-of-the-art" which can assist in integrated assessment.

I have touched upon these topics in this Section:

- o Risk Assessment and the Management of Integrated Assessment;
- o Sequential Decisionmaking;
- o Understanding the Decision Processes; and
- o Joining the Study of Decisions and Information Structures

2.1 Risk Assessment and the Management of Integrated Assessment

2.1.1 The Institutional Setting

Fisher, in his discussion of human health valuation (pp. 7-10) and "dealing with uncertainty" (pp. 13-15), is beginning to wrestle with problems of "risk", as well as that of the more traditionally dealt with "costs" and "benefits" issues. I have learned that economists cannot, and should not, dismiss all discussions of "risk" as either irrelevant, or as readily included within the cost-benefit framework. I have been working with EPA, OSHA, DOE, and other health/safety Federal agencies for many years, as well as "regulatory reform" projects more recently. My conclusion from this varied experience is that non-economists (and even economists turned public administrators) will trust economists only so far with the traditional tools of quantification. Economists, in treating risk, will have to make substantial advances to be included at the heart of the decisionmaking game in our environmental ("health and safety") regulatory agencies.

* E.g., "Environmental Economics", Chapter 4, in The Sixth Annual Report of the Council of Environmental Quality, 1976.

** Quarterly Journal of Economics, May, 1974, pp. 312-319; see also, J.V. Krutilla and Anthony Fisher, The Economics of Natural Environmentalists, RFF, Johns Hopkins, 1975.

*** Fisher touches upon these topics in this paper but does not extend the concepts beyond that of his previous writings.

I grant you: Given the substantial body of literature and the oft-repeated observation that risk--benefit, cost-benefit, and cost-effectiveness analysis methods should prove of substantial utility to those responsible for dealing with pollution activity, it frequently surprises advocates of these analytic methods how little is the explicit application of these methods in their allegedly merited EPA/OSHA/DOE contexts. The purpose of the Integrated Assessment project need not be to dwell on why this has or has not occurred, although recognition of the several attempts at application should play a role in the four case studies. More importantly, however, is arriving at: (a) an identification and description of the most effective ways in which these analytic methods could become useful to these agencies in performing their priority-setting and "unreasonable risk"* decisionmaking roles; and (b) an evaluation of the worth, i.e., the "comparative advantage", of these (allegedly) effective analytic approaches relative to other actual (and/or proposed), less analytical approaches in these decisionmaking environmental management areas.

Many inside and outside of EPA** believe that R/B (risk-benefit), C/B (cost-benefit), and C/E (cost effectiveness), or their combination, have a substantial applicability to the implementation of integrated assessment. However, no focused, concerted effort has yet been made to elucidate, evaluate, and implement alternative R/B and/or C/B frameworks and models in the environmental management decision-making context. Were such an effort made, certain hypotheses could be tested and critiqued:

- o R/B, C/B and C/E methods have to be differentially tailored and fit to the several, differing decisional contexts;
- o Properly conceived and placed within the realistic "sequential" process of dynamically unfolding data of uncertain quality and quantity, such analytic techniques would themselves be favorably judged in B/C or C/E terms;
- o "Mixed" systems -- both formal, analytic and less structured approaches -- are likely to provide the greatest overall support to the environmental management decisionmaking strategy; and
- o Increased use of these analytic techniques within the environmental management decisionmaking process may itself introduce bias in EPA/DOE/OSHA's approach to decisionmaking. Establishing a structured procedure in which unforeseen risks and costs and benefits which may arise may be more systematically dealt with may unintentionally increase the degree of "caution" exercised. This hypothesis needs to be "tested", also.

Quite clearly, valid and credible analysis of these hypotheses would provide those responsible for integrated assessment with substantial insight into managerial, administrative, information acquisition, and possibly organizational, budgetary, and staffing matters. I believe the i.a. process can potentially make a unique contribution by fostering methods of improving the specific mixture of methodological improvements and adaptation, meshing of methods and decision processes, and the requirement to test and implement the methods in a complex set of environmental management decision processes. Such methods, if they are to be useful in the health and safety regulatory area, must be shown to "prove" their mettle. The difficulties in application arise, I believe, because:

- o The design of risk/cost/benefit system applications, within multiphased decisional contexts of increasing detail and rigor, has never been fully implemented and/or evaluated within any complex public agency setting;

* This is the formal term used in toxics and pesticides regulation legislation. I use it to cover the wide range of health and safety "risk" jargon.

** Or OSHA or DOE.

- o The decisionmaking, information-using, public participative procedures and processes for making pollutant-related decisions have not been fully articulated, nor are they "trouble-free" (with or without the use of analytic R/C/B procedures), in the sense of having achieved repeated and successful determinations; and
- o There is no immediately and readily accessible assessment of decisionmaking risk, benefit and cost procedures, whereby apparent and obvious gaps could be "remedied" by the introduction of increasingly analytic techniques.

Were (a) the design of risk/cost/benefit analysis so advanced and accepted within a sequential decision framework, or (b) the procedures for making and justification of environmental regulatory decisions fully established and trouble-free, or (c) the detailed procedures for converting analytic results into environmental management decision and position documents fully spelled out and assessed, this integrated assessment project would be a good deal simpler from that which it will actually be. In reality, the development and application of each of these (three) highly interrelated components (a, b, and c) have, of necessity, proceeded at a pace most consistent with agency (EPA/OSHA/DOE) requirements; the current and unfolding state-of-the-art in scientific and economic methodology; and the priorities set by these agencies for research, program development and implementation of risk/cost/benefit analytic procedures. Unquestionably, the necessity for these agencies to evaluate significant numbers of pollutants and chemicals* is a most formidable undertaking requiring that whatever balancing methodology and system used provide pertinent valid information in a timely and cost-effective manner.

Another very important institutional consideration which needs to be studied further is the attitudinal set of the different actors in the regulatory decision-process, e.g.:

- o The legal profession's "agnostic", perhaps skeptical view, of increasingly formalized R/C/B procedures, e.g.: ** "The fact remains, however, that risk-benefit assessment may result in registration of carcinogenic pesticides, that biases may affect the assessment thereby making it less objective, and that some elements within the risk-benefit assessment remain unquantifiable. In determining whether the proponent has met its burden of proof and whether benefits outweigh risks, the decisionmaker must make a subjective judgment based on the facts before him and the weight he gives to them."
- o The economists', public administrators' and political scientists' views, are that policies on toxic substances control should be derived less from subjective than from explicit and reproducible opinion, e.g.: *** "To the non-economist, complete dependence on monetary values is frequently unacceptable. There are intangible or non-economic aspects of the environment that should also be assessed. To comply with their value system, a more comprehensive approach is developed." Here, as with the pure economics approach, the amount of risk-benefit data available determines whether a total or partial assessment is appropriate. The latter is more likely in view of the limited time horizon over which controls on toxic substances must be established.

* For example, the Toxic Substances Control Act encompasses over 70,000 chemical substances manufactured for commercial purposes and 4,000,000 substances now in research or development.

** McCarey, "Pesticide Regulations: Risk Assessment and Burden of Proof"; see also, articles by Campbell (12), Clement (16), and Roberte (106) in Bibliography, attached.

*** Tihansky and Kibby, "A Cost-Risk-Benefit Analysis of Toxic Substances", p. 26; also CONSAD, "Lead: Incomplete Information and Sequential Decision Processes", pp. 12-17; National Academy of Sciences, "Decision-Making for Regulatory Chemicals in the Environment".

Because risks and benefits are not necessarily translated into the same units, e.g., dollars, the optimization procedure is not straightforward.

Mr. Glenn L. Schweitzer, former director of the Office of Toxic Substances, puts these institutional problems this way:*

Even though toxic substances are by definition dangerous to health or the environment, there seems to be general agreement that in developing control strategies some balancing of risks and benefits is in order, as reflected in the EPA action on Benzidine. In the past, elaborate cost/benefit models have frequently had little operational relevance. At the same time we must do better than those past efforts that tend to focus only on the short-term, direct costs of environmental controls which are susceptible to quantification...

What should be the approach to risk/benefit analyses? With regard to the known problem substances, I suspect that in the short run we will do little better than weighted checklists to be used as general guidelines for at least surfacing some of the concerns before decisionmaking time. Case studies of specific past decisions should be particularly helpful in this regard. In the longer term, I don't know if a more objective approach can be developed that is broadly applicable to balancing risks and benefits.

2.1.2 Technical Issues in Risk Assessment

Fisher's paper did not touch on a number of risk assessment issues which are crucial to the successful implementation of R/C/B analysis for improved environmental management. These are briefly discussed in this Section.

2.1.2.1 Single or Composite Definitions of "Unreasonable" Adverse Hazards

The question has arisen many times as to what is meant by the phrase "unreasonable adverse hazard" to human health or the environment: how are hazardous pollutants to be identified and when does a pollutant become "hazardous"? Obviously, in designing a risk/cost/benefit system, some general consensus must be reached as to what is and what is not hazardous. "Hazardous" can be viewed as any chemical (taken broadly) which threatens human health either directly or indirectly. It can also be defined to be any chemical which threatens some species or adversely affects the environment and obviously a definition combining both hazards to humans and the environment is possible. However, many chemicals which cause environmental damage may not significantly affect human health and vice versa. In such cases, how does one evaluate and rank chemical hazardousness?

Another definition states that hazardousness is a function of the toxicity of the chemical to human and other species, its persistence in various media and rate of metabolic degradation, total usage and methods of production, distribution and application. This definition is somewhat more attractive for it recognizes that volumes or quantities of chemicals distributed affect the total hazard and that toxicity can be counterbalanced through higher natural degradation rates and care in the production, distribution and application stages.

While some agreement is likely to exist as to what an "adverse hazard" consists of, the question of what is "reasonable" and what is "unreasonable" usually remains. EPA and OSHA have historically said that involuntary risks of exposure or those taken by the population at large are more significant or important than the voluntary risks that are "accepted" by chemical producers, distributors, applicators and users.

* "1974 -- A Year of Transition", EPA, 1975

In this context, for example, a more hazardous chemical is one which may accumulate in the food chain in such a way as to expose an unknowing and unsuspecting population.

2.1.2.2 Integration and Aggregation Issues

By definition, a risk/cost/benefit system must contain numerous information bases, each of which measures different dimensions of hazardousness and risk. Aggregation of hazard and risk-related data by various means normally simplifies the interpretative skills and time demands placed on the user of such information. On the other hand, a disaggregated presentation of information (human health hazards versus environmental impacts) may be desirable for the subsequent risk/cost/benefit analysis of "decision theoretical" approaches. Designing a standard framework for total hazard evaluation should help to minimize the perceived procedural variances that result from current evaluations, and given some logical integration and aggregation of impacts, would appear to simplify the administrative use of the risk/cost/benefit outputs. Health effects variables, perhaps, should be aggregated provided that high priority information, such as carcinogenic characteristics, test results or cases, is not obscured by the aggregation. The ultimate goal should be to quantify all types of variables related to the risk analysis without losing priority information (as exemplified above) and to describe narratively those variables which are not quantified. After such quantification, a determination of which variables are relevant and which are comprehensive can be made.

2.1.2.3 Level of Aggregation (Total Number of Categories* Created)

There is always a tradeoff between creating many fine groupings with little coverage/data per grouping -- or creating only a few major groupings. With larger groupings, larger "sample sizes" will lend greater statistical accuracy to the results quantified in each group. With smaller subgroups there will be some sacrifice of statistical reliability for the sake of determining which subgroups reveal substantially greater or less impact than others. The choice of level of aggregation for modules within an entire risk/cost/benefit system itself must be made on the basis of how useful it is to detect the small subgroups with impacts substantially different from the average impact in the large groups.

In general, the smallest groupings which can provide reasonably reliable data are to be preferred, as further "lumping" of comparable data is fairly straightforward.

Classification of hazard measures into major groupings is another fundamental aspect of measurement. An example of a potentially useful taxonomy might be: (1) human health, and (2) environmental hazards. One criterion for such a classification would be that units across categories could never be added directly but only displayed as separate elements in the summary tabulation.

Specification of Units should be, whenever possible in familiar units and/or in units which lend themselves to or suggest mitigation strategies. While it may be very tempting to reduce everything to one common denominator -- dollars -- such a simplified measure can in no way adequately reflect all the hazards and risks associated with the given pesticide.

2.1.2.4 Definition and Measurement of Risk

In its broadest terms, "risk" can be defined as the potential realization of unwanted consequences as a result of a specified action or inaction. In the case of risks associated with an action, the analyst is concerned with incremental risk, i.e., the difference between the risk that exists as the result of the action and the risk that would prevail if no action were taken. Risk is

* Referring to categories of pollutants, toxics, etc.

typically specific to particular consequences and a finite universe, such as the risk of death to the United States population, or the risk of annihilation of a specific species of birds in a particular habitat.

In addressing the problem of risk, the analyst must address three major tasks. He must identify the risks associated with the proposed action or inaction, he must attempt to measure the risk, and he must attempt to evaluate the risk*. The operational problems involved in the performance of these tasks involve the identification and measurement of potential consequences, the estimation of the probabilities that the particular consequences will occur based on the universe of people, biota, or things that will potentially suffer the consequences; and finally, the assignment of some measure or value to the combination of the probability and the consequences.

The undesirable consequences of an action or inaction can be expressed in economic, health, or environmental terms. These consequences can be jobs lost, plants closed, crops lost, deaths, injuries, elimination of a species, or destruction of a unique physical resource. So long as the occurrence of the consequence is only a possibility, then there is only a risk of that undesirable consequence happening.

2.1.2.5 Concluding Remarks on Risk

I do not, currently, view any single discipline (e.g., economics, operations research, toxicology, ecology) having all the answers for the problems raised above regarding risk assessment and measurement. However, I anticipate that the integrated assessment should attempt to mesh the knowledge of its variously experienced staff members with the needs of this project, to make sufficient advances in the risk assessment area -- within the context of R/C/B analysis -- to assess the potential utility (of employing R/C/B) to the environmental management decision processes.

2.2 Sequential Decisionmaking

I wish Fisher had extended, further, his discussion of how better to deal systematically with uncertainty and irreversibility (Fisher, op.cit., pp. 13-15). This is one of the most important and pressing problems in all of environmental management, so some comments are in order here.

One of the most significant and unique contributions the i.a. project can make is to provide environmental managers with sophisticated insights into the notion of differential "levels" of application of R/C/B techniques -- different levels of detail, abstraction, hierarchical tier, data validity, credibility, validity, and legal standing -- depending upon the stage of the environmental management decision process to which the analytically formal system is being applied. Illustrative (re EPA/OSHA/DOE-ENV) are the:

- o Priority-setting versus "unreasonable" risk decisions;
- o "Yes-no" testing decisions versus "non-zero" testing levels;
- o New versus existing chemicals; and
- o Other distinctions.

* Fisher has an analogous classification.

2.2.1 Levels and Hierarchies

Proponents of R/B/C analytic frameworks have typically characterized their use in environmental contexts as more that of a logical framework as a formula -- a framework, in fact, to "be used at many levels, from back-of-the-envelope 'quickie' decisions (e.g., whether or not to investigate a problem more thoroughly) to large-scale formal analyses,...".* And the TSCA Strategy discusses and differentiates which of "several kinds of decisions will determine priorities under TSCA ... (in all of which) relative risk will weigh heavily."**

My own work in this area*** utilizes, as an illustration (reproduced here as Exhibit 1), an "informed perception of the organizational framework in which the analyst is performing his task", as well as the flow which decisions might follow within an agency, as being essential to focused, efficient analysis in a sequential process. Exhibit 1 describes on the vertical axis three levels of a typical Federal organization, as well as Executive, Legislative, and Judicial Branches (Level I) and non-specific outside influences (Level V).

The purpose of such a flow chart is to tell the R/C/B analyst the context into which his work must fit. The context has an organizational aspect to it, i.e., the analyst must know his role vis-a-vis the decisionmakers and outside parties, what kinds of actions fall into his realm, and what information flows between levels are involved. The context also has a time or sequential aspect to it, i.e., what stage in the analytical process the analyst is working at a given time.

The intention is not to be didactic or to presume to dictate reporting relationships between elements of environmental agencies, and/or an agency and those outside of the agency, but rather to illustrate the concept of a hierarchy of decisionmakers, and how the work of one level can, at times, call for, be initiated by, or receive guidance from another level. The placement of these sequential decision steps at different hierarchical levels, i.e., an understanding of the structure and relationships involved, is necessary if risk/cost/benefit analysis is to make its optimal contribution to the decision process.

Again, illustratively, information about potential problems requiring further review and analysis comes from several of the levels outlined in the chart. The first step portrayed in the sequence is a preliminary screening process (A) that seeks to deal with the regulatory "fact of life" that there are vastly more potential "environmental" problems than can be considered thoroughly (or at all) by the regulatory agency, given its time and resource constraints. Therefore, one way or another, the process should include some kind of "early warning system" by which it can select those problems which appear most pressing and then subject them to a more detailed analysis concerning regulatory alternatives and their risks, benefits, and costs.

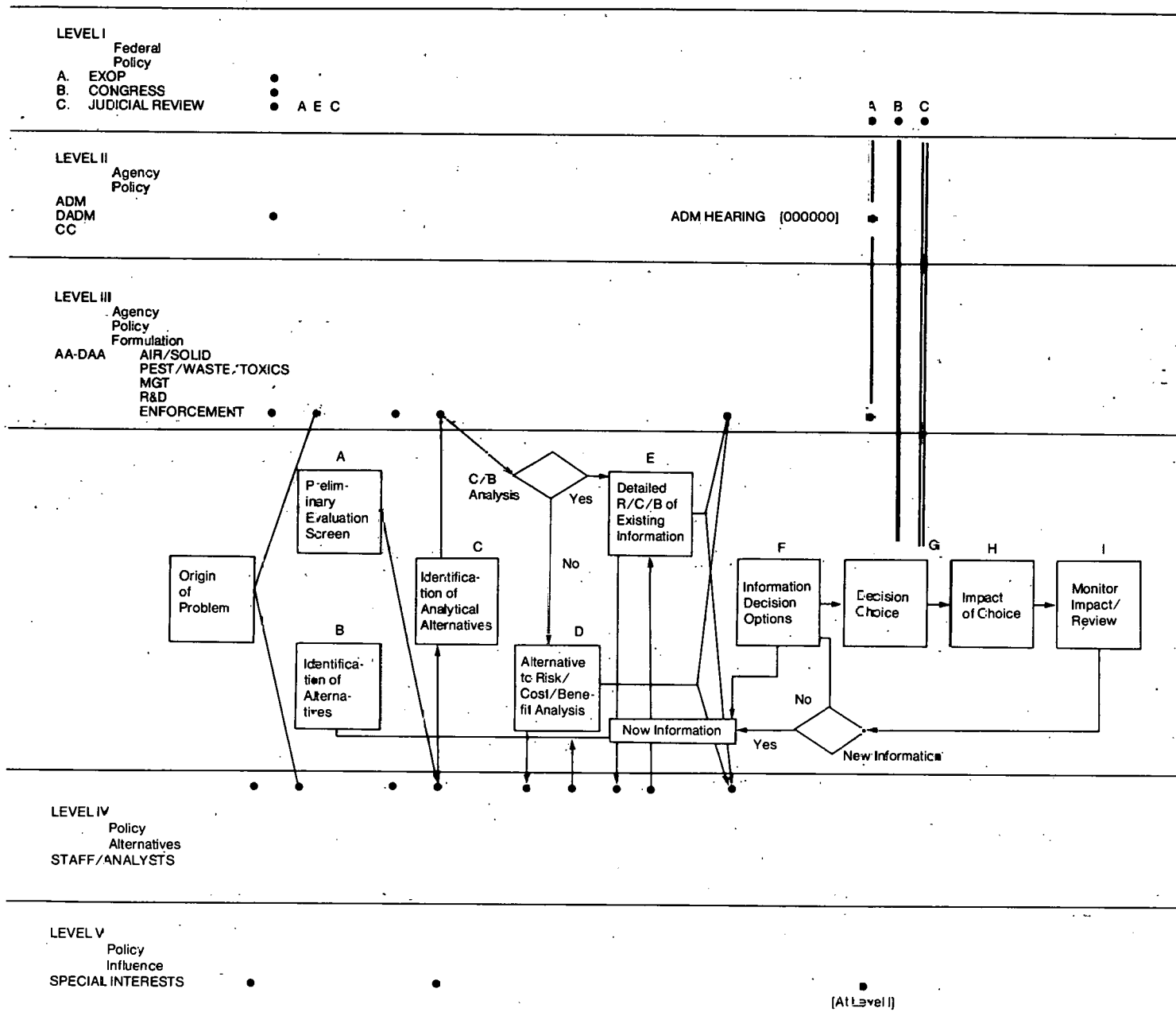
2.2.2 Additional Comments About Sequential Decision Processes

Screening is not necessarily a "mini" risk-cost-benefit analysis, even though it uses many of the concepts of risk, benefit and cost. Rather, it should be a "quick look" at problems in terms of a few criteria, and a method of selecting those few areas which merit an eventual full analysis.

* National Academy of Sciences, "Decision-Making for Regulatory Chemicals in the Environment", p. 194.

** Op. cit., p. 7.

*** A Subject Reference: Risk/Cost/Benefit Analysis, pp. 3.63-3.72; also, "Lead: Incomplete Definition and Sequential Decision Processes".



One criterion which can be used fruitfully in the environmental area is "hazard". This is generally phrased in terms of the "population at risk", i.e., how many people are exposed to what sort of hazard. The gravity of the hazard and the numbers exposed would then (somehow) be translated into an index of priorities.

Other criteria which might be used, either in combination with or as a substitute for hazard, are "gross benefits", "gross costs", "irreversibility of damage", probability of harm", etc. In many instances, the screening is performed by experienced analysts who somewhat intuitively sense an "important" problem. Thus, in large part, the subjectivity perceived "magnitude" of the problem may be the overriding screening criterion, although increased rigor would be pursued during this project.

As indicated, "outside sources" may perform the screening function, and in this case any number of persons could perform it. When the screening is done in-house, however, it is generally performed at the staff level. Once this analytic process has been completed it is referred to higher level decision-makers for review and choice of those areas which should be investigated further.

The screening process is, therefore, carried out by staff analysts but largely utilized by decisionmakers as a means to prioritize and recommend for full benefit-cost analysis certain regulatory problems facing the agency. On the other hand, screening often results in a decision not to undertake further action, and so helps to focus available benefit-cost resources on the most important issues.

Other aspects include:

- o Identification of Alternative Scope and Depth. The scope and depth of analysis need to be limited by available resources. Resources may be available in varying degrees depending on other agency internal and external commitments. The resources usually available consist of time, manpower, and dollars. The dollars may be used to extend the agencies' capabilities through the use of consultants or other contractual arrangements. Depending on the agencies' role or charge, these resources may be difficult to generalize. For example, an enforcement-oriented agency may not have the technical depth or expertise to engage in a full-scale R/C/B study and therefore the time-manpower aspect becomes submerged and the existence of specialist resources assumes prime importance. With input from the analysts and others, the decisionmaker can specify those categories and impacts he considers important and the precision and comprehensiveness of the analysis he feels is necessary.
- o Alternatives. The selection of the technical and policy alternatives to be evaluated and compared in the R/C/B analysis should be selected by the decisionmaker from a full range of options. He should consider information from the analysts and other sources, but the selection should be done by him.
- o Technical. From the standpoint of technical alternatives, several avenues should be explored, followed by a focusing on a few viable approaches. These alternatives could consist of chemical substitutions, method modification or unique applications of existing control technologies.
- o Policy. Policy alternatives should be considered after the various parameters of the technical alternatives have been assessed. Such policy decisions come into play when the selected technical alternatives are deemed to be restrictive or costly. One example of a policy alternative could be a deferral of a compliance date to allow sufficient lead time for implementation by the affected parties. As noted above, the selection of alternatives to be analyzed in more detail and the scope and depth of the analysis are important parts of the decision process. The choice of alternatives for more intensive study should not be made solely by the analyst, but rather by the decisionmaker using information from a broad range of multidisciplinary sources, and covering a full range of alternatives.
- o Selection of Analytical Techniques. Once the technical alternatives, the range of policies to be analyzed, and the scope and depth of analysis have been determined, it is up to the analyst

to decide which tools best provide information upon which an optimal choice can be made. It should be understood that each technical alternative and its policy vehicle may have different analytical requirements in terms of benefit-cost analysis. It may not, in fact, be necessary to use a complete benefit-cost analysis to evaluate each alternative (Step D instead of Step E in Exhibit 1). The decision as to the type of analysis to be conducted should be based on the resources available and the information necessary to solve the problem adequately. The appropriate analysis may range from a simple benefit-risk or cost-effectiveness analysis to a full treatment of all the kinds of economic and environmental benefits and costs. This step in the sequence represents the detailed evaluation of benefits and costs using existent information treated by the other panels. The purpose of the preliminary screening and consideration of analytical alternatives before proceeding to this step is because of what can be a considerable resource cost of detailed benefit-cost analysis.

- o Information/Decision Options. Here, the decisionmaker reviews the analyst's R/B/C results, evaluates the quality of the information, and determines whether or not the information base is sufficient to base a decision.
- o Sufficient Information. If the information is judged to be sufficient, the decisionmaker can either: (1) choose an alternative or outcome (i.e., make the decision), or (2) make no decision and refer the question with the analysis to a higher level of decisionmaking in the Agency.
- o Insufficient Information. If the information is judged not sufficient to allow the decisionmaker to make a final decision, he can: (1) postpone the decision and await additional information that is then fed back into the identification of alternatives and benefit-cost steps, or (2) make an interim decision to be reviewed when more information is available (e.g., interim standard). It should be noted that there may be significant risk and economic costs and impacts from either postponement of the decision or making an incorrect interim decision. Assessment of available information is a key factor, and identifying gaps and weaknesses is an important part of the analyst's role. The decision as to whether or not the existing information is sufficient is the decisionmaker's, but the analyst's recommendations and evaluation should be important considerations. If information is considered insufficient, a further decision must be made as to whether or not additional information should be generated. Factors influencing this decision include: (1) seriousness/importance of the problem, (2) cost of generating more data, and (3) expectation of success and benefits of obtaining more information.

2.2.3 Analytic Representation of This Sequential Process

The R/C/B analyst will tend to consider the process of dealing with a specific pollutant as a "project", from beginning to end. The usual approach of the risk-cost-benefit analysis is to evaluate this "project" by comparing the currently perceived stream of discounted risks (to the extent they are measurable) and benefits expected to accrue with the currently perceived stream of discounted expected costs. That is, risks, costs and benefits are estimated solely on the basis of the available information set. Naturally, the usefulness of this approach is directly dependent upon access to reasonably precise estimates of what these risks, costs and benefits will be. Certain projects, particularly when their human health impact is being considered, do not, however, suggest such information is readily available. Obviously, it would be difficult to precisely forecast the human health effects of a project, whether good or bad, if the health context itself were not well understood. Therefore, projects might arise in which it would be possible to collect better estimates of the expected costs and benefits by allowing the project itself, or a pilot representation, to proceed while observing its performance closely.

In projects of this type, the means of project analysis would naturally be that of a sequential decision process. In each period in which the project (or a pilot project) were proceeding, the expected future risks, and benefits been collected to terminate the information apparatus, and to decide finally if the project should be allowed to proceed or will be abandoned? Finally, I have been involved and have considered the problems of the implementation of this approach -- no minor aspect of this problem.

2.3 Understanding the Decision Process

There is little question but that the various analytic methodologies must be accompanied by appropriate strategies for using them in the environmental management decision process. This requirement clearly reflects the realization that a risk/cost/benefit analysis does not autonomously and/or automatically produce a decision. The public policy decisionmaker is not content to rely on the mechanistic use of risk/cost/benefit calculations, any more now than he used to be. Technical developments in the decision science field have increasingly demonstrated that decision techniques and strategies can significantly improve the exercise of human judgment, but can never replace or supplant it*.

But the decision scientists have, over the years, devised an impressive array of decision-aiding techniques which can be tested and adapted by decisionmakers within the context of the environmental management process. These techniques include the well-known gaming, Delphi, bargaining, and subjective scaling techniques, plus others. But these techniques must be adapted and fitted into the environmental management process, just as the R/C/B methodology itself must be fitted into the process.

2.3.1 Investigating the Environmental Management Decision Process

In initiating its study of a specific decision process, the integrated assessment project team should briefly review the pertinent legislation, judicial decisions, agency regulations and other mandates to determine procedures and policies regarding the particular regulatory framework. Included in this review should be:

- o Relevant legislation and its background;
- o Judicial and administrative law decisions;
- o Agency regulations in the chemicals area;
- o Other mandates regarding toxics (e.g., enforcement policy statements); and
- o Strategy documents.

In reviewing this material, attention should be directed to delineating the data requirements, unique information required, internal decisionmaking documents, required risk/cost/benefit analyses and time constraints stipulated by each document. Furthermore, note should be made concerning the variations, if any, in these requirements for the different "triggers" in the process.

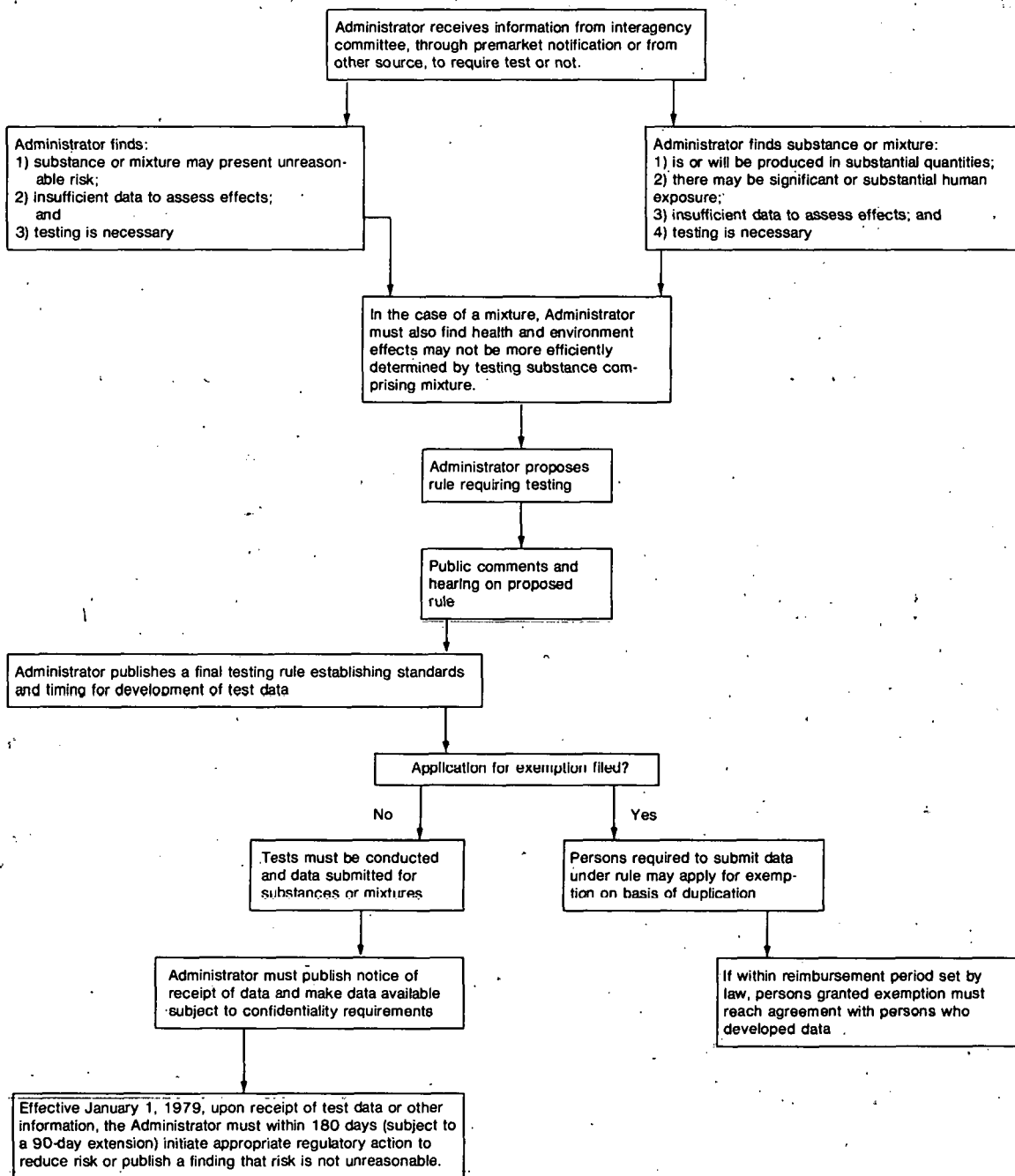
2.3.2 Analysis of Decisions

Decisions required by the system should be identified and the relationships among them should be determined and flow-charted. Exhibit 2 is an illustration of such a logic-flow chart.**

* W.A. Steger, "On Applying the Tools of Administrative Science and Normative Decision-Making in the Office of Pesticide Programs: Developing a Research Strategy", (prepared for Office of Strategic Studies, EPA), November, 1974.

** A number of flow charts of this process currently exist, e.g., of Sections 4 and 5, TSCA of 1976, in the Cleary, et al., "Memorandum on the TSCA of 1976", reproduced in Environmental Reporter, Monograph No. 24, March 11, 1977, Appendix A, pp. 29-42. The type of flow charts we will require will be more in the form of Exhibit 1, above, than those used in describing legal logic, since we are interested in hierarchies, timing, interrelationships and information flow.

EXHIBIT 2 — Flow Chart — Section 4 Testing Requirements (TSCA)



Decision-flow analyses are usually self-justifying. They often reveal important decisions that are being made by default, and they disclose interdependent decisions that are being made independently. Decision-flow charts frequently suggest changes in decision responsibility, organizational structure, and measurement of performance.

Decision analyses vary from coarse to fine grained in terms of degree of detail. It is essential to begin with a coarse analysis of all of a system's functions and then proceed to a fine analysis of one or a subset of functions.

2.3.3 Analysis of Information Requirements

"Models", implicitly or explicitly, provide a means of determining what information should be included in a system. Every decision can be described by some type of model. In the sense used here, a model is a representation of a decision process. It is a formalization of the relationships which are asserted to exist among data required for decision. The value of a model lies in the ability it provides for interpretation of the set of data, generalization from it, and decisionmaking based upon it.

Models range from highly formalized mathematical statements of relationships (e.g., linear programming and statistical models), to logic statements of the steps involved in a task and the rules for carrying out those steps (e.g., a program for computing payroll deductions), to implicit understandings and rules for choice lodged in the minds of decisionmakers.

Environmental management decisions can be classified into four types as they relate to such models:

- o Decisions for which adequate models are available or can be constructed and from which optimal solutions can be derived. In such cases the decision process itself should be incorporated into the information system thereby converting it to an automated control system. A decision model identifies what information is required and hence what information is relevant.
- o Decisions for which adequate models can be constructed but from which optimal solutions cannot be extracted. Here some kind of heuristic or search procedure should be provided even if it consists of no more than computerized trial and error. A simulation of the model will, as a minimum, permit comparison of proposed alternative solutions. Here, too, the model specifies what information is required.
- o Decisions for which adequate models cannot be constructed. Research is required here to determine what information is relevant. Such research may include surveys of data presently contained in the municipal system and its use. It may include surveys of users, to determine what information should be contained in the system but it is not presently.
- o If the decisionmaking about information requirements cannot be delayed for the completion of such research or the decision's effect is not large enough to justify the cost of research, then judgment must be used to determine what information is implied as relevant by the decisionmaker.

2.4 Joining the Study of Decisions and Information Structures: With and Without R/C/B Methods

Two elements of central interest for a study of integrated assessment methods are the information structure, which exactly defines the information available to each person or decisionmaker at each instant of time, and the decision rules, which specify the actions that occur given a particular information pattern. We would anticipate that both the information structure and the decision rules of a specific environmental management problem would be modified, to a degree, with the introduction and implementation of R/C/B methods. Physical considerations -- for example, computers and communications aspects -- will often play a large part in the determination of feasible or desirable information structures and decision rules. Furthermore, the peculiar psychological traits of people -- their tendencies to misunderstand, make mistakes, compensate for system deficiencies, or depart from instructions -- introduce

special and difficult problems into the design of an improved system. It is our belief, however, that the study of information structures and decision rules is critical to the successful testing of R/C/B techniques and definitely should receive special attention in this project.

Students of this decision process -- particularly the so-called "normative" decisions -- have developed logical frameworks, showing the sequence of steps involved in that process. For example, the 1975 NAS report (Decision-Making for Regulating Chemicals, pp. 34-36) describes the process of evaluating existing information, the identification of needed new information and feedback between these, the choice of actions and the ultimate decisional impact.

In my study of the decision rules and information structure, both in current use and prospectively with increased use of R/C/B methods, I have attempted to evaluate the effectiveness of the decision process, both with and without the use of R/C/B analysis (see Exhibit 3). I believe the integrated assessment project can make a contribution to this type of evaluation.

In a mixed system, with greater use of R/C/B methods, environmental managers and analysts would need, jointly, to make the determination shown in Exhibit 4 (illustrating the toxic substances decision process) whereby the goals of the toxic determination process serve to condition the degree to which formal R/C/B analysis can be utilized.

2.5 Concluding Remarks About Scope and Content

I do not recommend that the current project make a 180° turn to accommodate and/or follow up on the above comments. Nor do I believe that the study has to make such a change in direction since I read into both Holdren's and Fisher's papers many elements of the considerations raised above.

3.0 ISSUES COVERED IN FISHER'S PAPER

A critical assessment of Fisher's paper needs, in fairness, to include the more theoretical and analytic of Fisher's work (partially cited above); however, I have not had the time and luxury to do this so, instead, I will provide commentary on the substantive areas Fisher has briefly touched upon in his excellent "discussion for the layman". If he has already discussed these matters, in a similar fashion in other places, I hope he will pardon me.

3.1 Costs, Benefits and (Other) Impacts

In the world of regulatory reform analysis, while costs are KING, I believe impacts are probably GOD. This is perhaps unfortunate, particularly for economists who, like Fisher, are expert in developing cost categories and classifications which are non-overlapping and comprehensive. But the world isn't perfect and economists, in supporting regulatory/standards development, should attempt to better match up categories used by regulatory decisionmakers with those used in cost-benefit analysis.

The latest, evolutionary impact focus is on "regulatory analysis", superceding "economic", "inflationary", and other like impact statement requirements. Let me attempt to bring you up to date, as I understand it.

What we are looking at, re the setting of health and safety standards, is the trend, which has emerged with the advent of the Carter administration and its top economic advisors, inflation fighters, and deregulation advocates. As would be expected, EPA and OSHA are caught up in the eye of the storm. This is concerned with the advocacy by those favoring "deregulation" to also promote more generalized economic and market-oriented incentives to achieve compliance (or, at least, a mix of controls and incentives).

EXHIBIT 3: Evaluation of the Effectiveness of the Decision Process

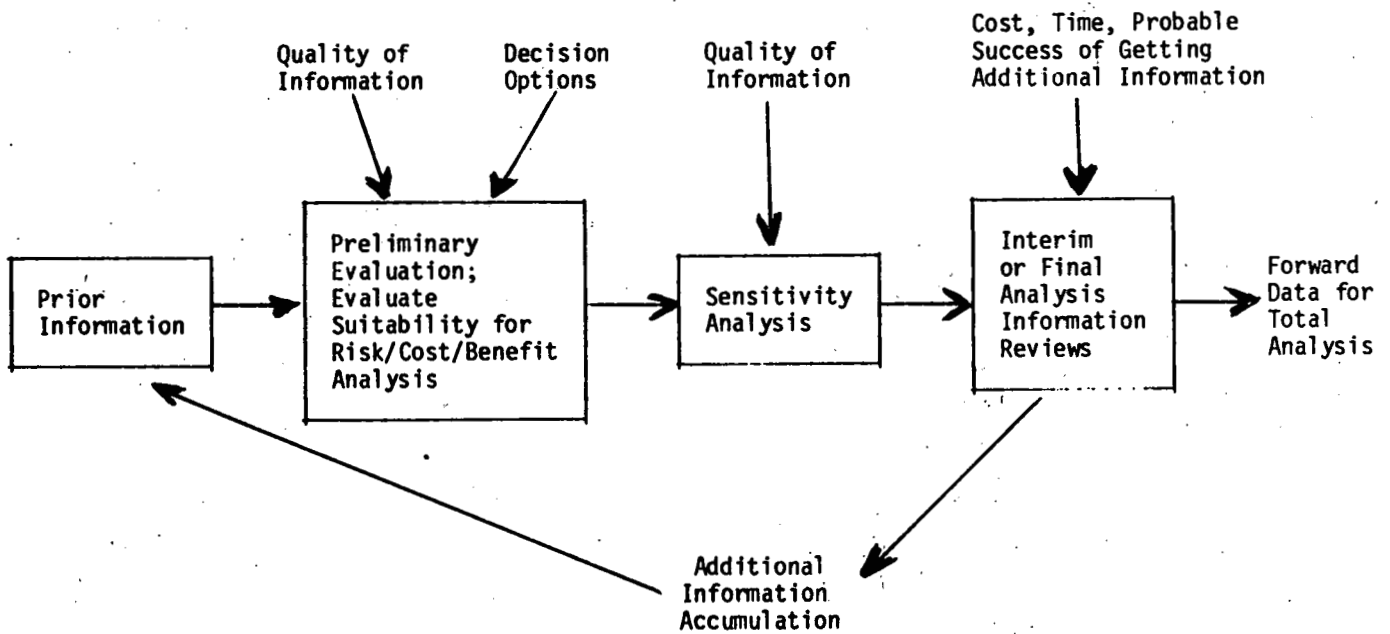
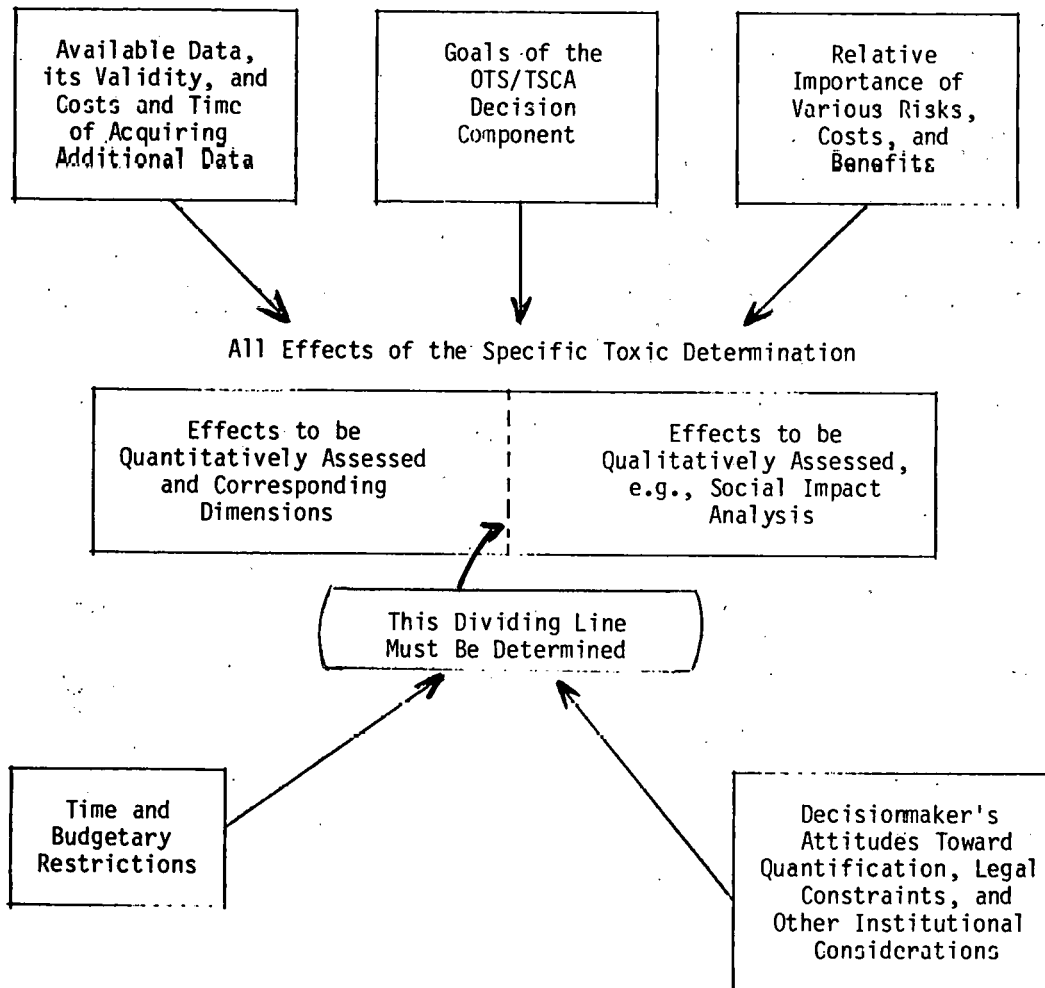


EXHIBIT 4: Factors Affecting Use of R/C/B With Decision Process



These trends have emerged over the last eight to ten years, during which the regulating and rulemaking authority of Federal agencies has been substantially expanded as a consequence of increasing demands for protection of individual, social and environmental welfare. While the results of this heightened activity has provided an impressive list of achievements and created new incentives for progress in all of these areas, there have been criticism of the mounting burden of red tape, forms, paperwork, and general administrative activity created by this growth. The legal precedents governing such cases are often unclear and the interpretation of the court's recent decisions reflect the uncertainties of most experts today regarding what constitutes an "undesirable" or unlawful action. Reliance on Congressional intent embodied in various pieces of legislation is only partially helpful for clarification purposes as Congress itself has vacillated on critical issues such as environmental and health protection, economic stability, energy, agriculture, transportation, states versus Federal roles, and private versus public intervention. And the Executive Branch, itself, and even different parts of the same Department are often viewing "different parts of the same elephant" -- each with different "marching orders", be it by law or by executive judgment.

All of this complexity, exacerbated by the requirement for impact studies (Executive Orders since 1975) explain why standards development has been a more time- and resource-consuming undertaking than had originally been anticipated. And the most current, controversial weighing of inflationary impact against the benefits of cotton dust regulation (in OSHA) has introduced an additional complexity -- albeit not yet part of any formal process -- and some additional delay.

It is not yet four years since November, 1974, when President Ford issued Executive Order 11821 requiring all Federal departments and agencies to prepare "inflationary impact statements" (IIS) for all legislative and regulatory proposals that may have a "major" impact on the economy. In response to this Order, OMB issued Circular A-107 prescribing guidelines for the identification and evaluation of regulations or rules. These guidelines required that an IIS include analyses of*:

1. Cost impact on consumers, businesses, markets or Federal, state or local government;
2. Effect on productivity of wage-earners, businesses or government;
3. Effect on competition;
4. Effect on supplies of important materials, products or services;
5. Effect on employment;
6. Effect on energy supply or demand.

* In addition, OSHA and EPA should provide as part of this evaluation:

1. An analysis of the principal cost of other inflationary effects of the action on markets, consumers, businesses, etc., and, where practical, an analysis of secondary cost and price effects. These analyses should have as much quantitative precision as necessary and should focus on a time period sufficient to determine economic and inflationary impacts;
2. A comparison of the benefits to be derived from the proposed action with the estimated costs and inflationary impacts. These benefits should be quantified to the extent practical; and
3. A review of alternatives to the proposed action that were considered, their probable costs, benefits, risks, and inflationary impacts compared with those of the proposed action.

OMB Circular A-107 assigned the responsibility for the development of criteria determining whether proposed regulations are "major" to agency heads. Each agency was also ordered to develop procedures for the evaluation of proposals according to the guidelines stated above.

In making the required cost impact analyses above, consideration was also to be given to the possible negative effects on productivity that may arise through any of the following:

- o Reduction or restriction of industry (output) capacity or capital investment;
- o Increase in labor man-hours per unit of output;
- o Increase in barriers to substitution of processed or raw material suppliers; and
- o Reduction or restriction in adaptation of new technologies, equipment processes, or skills.

During 1977 and early 1978, there was much OMB/CEA/COWPS discussion of ways to "improve the regulatory process" and, not surprisingly, the IIS became a major focal point for the analytic and informational requirements of what eventually became E.O. 12044.

Issued March 23, this Executive Order directed each executive agency to: (1) provide maximum opportunity for public participation in the regulatory process; (2) conduct extensive analyses for those regulations which might have "major economic consequences"; (3) periodically review existing regulations; and (4) eliminate or improve inadequate regulations. Under the proposed OSHA/EPA/DOE procedures a regulatory analysis would be performed for any regulation likely to result in an increased cost of \$100 million or more in any one year for the national economy, or a \$50 million or larger increase in costs or total revenues in any one year for a specific segment of the economy. A regulation that would result in a "direct dislocation" of 10,000 or more jobs, or a substantial limitation on competition in a market doing \$100 million or more of business per year, also would be selected for analysis.

A regulatory analysis, according to the proposal, would include:

- o A statement of the problem and regulatory objectives;
- o A description of the major acceptable alternative regulatory actions, and the effectiveness of each alternative;
- o An estimate of the economic consequences of the major alternatives; and
- o An explanation of why a given alternative was selected for a proposed action.

It certainly is not yet fully clear as to the E.O.'s ultimate effect on the impact assessment process in DOE, EPA, and OSHA. However, I see these to be the likely "major" differences between the implementation of E.O. 12044 and its predecessors:

- o Increased emphasis is placed on the use of economic analysis;
- o Increased formalization of the rulemaking process;
- o Criteria for what is "significant" has changed;
- o Increased sectoral and geographical detail is required;
- o Economic consequences of alternative approaches are to be analyzed;
- o Earlier public involvement is requested;

- o Periodic review of rules is required; and
- o Semi-annual agenda for rules review and development are required.

I recommend that the integrated assessment project team select one or more areas of regulatory analysis importance to study in some depth.

There are a large number of options to be selected and judgments to be made regarding these proposed procedures, if they are approved (more or less) as they are. The adversary nature of this process conditions the choices which can be made. For example, an interrelated set of judgmental options and decisions concerning "levels of significance" and degree of "major-ness" is called for. A subordinate decision is concerned with ascertaining the "degree of public interest or controversy". One can see where EPA, DOE and OSHA needs to be concerned about other factors, in determining significance and "major-ness" in addition to those enumerated in the draft interpretation of the Executive Order. It is not clear, for example, how the urgency of a proposed regulation, relative to its prospective "life and limb" benefits, is to be weighed in determining whether to perform a regulatory analysis, how that analysis is to be performed, and the timing of the analysis.

E.O. 12044 will increase the likelihood that significant tradeoffs will need to be made. A dilemma continually faced by OSHA, for example, is the weighing of the legal mandate to protect workers "to the extent feasible" against the economic impacts that are likely to occur if this is carried to its ultimate. Does "feasible" involve merely technical questions regardless of cost, or does "feasible" involve a tradeoff of health and safety against jobs? Does "informed consent" and "hazard pay" permit OSHA to settle for standards which are short of ideal in order to reduce economic impacts? OSHA's recent coke oven and cotton dust rulemaking procedures have involved situations in which such tradeoffs were necessary. OSHA was able to interpret its role so as not to fall short of its goals, although the rules sometimes involve provisions which will permit gradual adjustments for certain heavily impacted segments of an industry.

One of the lessons of the history of rulemaking in this adversary setting is that impacts often turn out to be much less than the adversaries predict them to be. Mostly, this is due to the ingenuity of technological development (i.e., "necessity is the mother of invention") and to the number of options which are open to industry in reality (e.g., substitution). The experience with PVC demonstrates this ability to adjust and the dangers of following the "conventional wisdom" which was expressed in the rulemaking on PVC, and which later proved to be grossly in error. In addition, the cotton dust procedure shows the usefulness of economics in identifying industrial segments which are worthy of special consideration in implementation of rules (if not the ultimate form of the rules adopted).

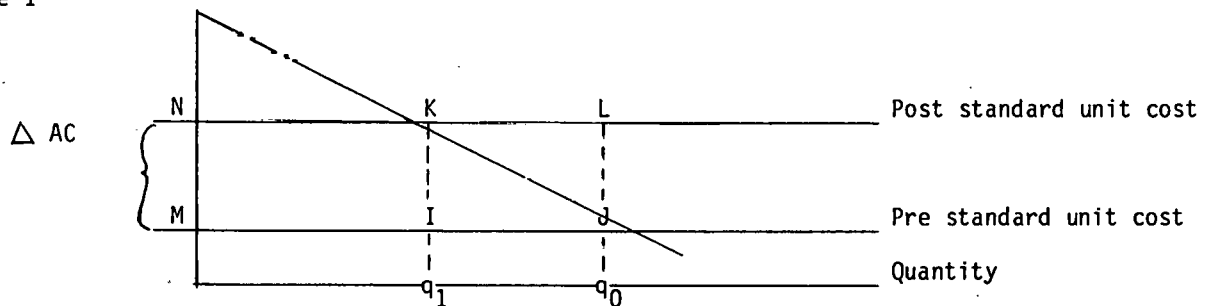
3.2 Imputing Values and Price Changes

Fisher's discussion (pp. 6-7) raises the questions of market price changes following the introduction of a specific standard, and the resultant consequences for producer and consumer surplus. In some work for OSHA in which I've been involved, an attempt has been made to develop an operational procedure to implement the "partial equilibrium" economics called for here.

The first step in these standards-setting economic impact studies has been to determine the cost of compliance for a given industry. Engineering analysis provides an estimate of the increase in the unit cost of production. In order to measure total cost of compliance for the industry, an analysis of the impact of the change in unit cost on the total output of the industry must be made. The purpose of this analysis is to assess producer price response to a change in cost structure and consumer demand response to a change in price. Therefore, a by-product of the analysis of the cost of compliance for a primary impact industry is a determination of the price and output effects of compliance with the standard applied to that industry.

This "engineering economics" analysis has been used to establish a bench-mark, or upper limit to the cost of compliance for an industry. If producers make no price response to a change in their cost structures, then the total cost of the standard will be the increase in unit cost ($\Delta A.C.$) multiplied by the unchanged rate of output (Q_0) of the industry. $\Delta A.C. \cdot Q_0$ represents the maximum possible cost. However, if the industry raises its price in response to the increase in its unit costs, consumers may make a quantity adjustment that will reduce the total cost of compliance. Quantity adjustment reduces the cost of compliance roughly by the factor $1/2 \Delta Q \cdot \Delta P$ where ΔQ is the quantity adjustment associated with the price change ΔP . This is shown in Figure 1.

Figure 1



In Figure 1 the area MNLJ represents the total cost of the standard if producers make no price response to its imposition. In this case all of the cost takes the form of reduced profits for producers. Points K and J lie on the demand curve for the good. If the initial price were Jq_0 and producers made the price response of adding $LJ = KI$ to their selling price, the quantity purchased would fall to q_1 . Since price was raised to cover additional unit cost, producers bear no losses. Consumers lose $\Delta AC \cdot q_1$ through higher prices on the amount they continue to purchase. They also lose the consumer surplus, KIJ , because they can no longer purchase the increment, Δq , at the old price. The total consumer loss is therefore $NMIK + KIJ$ or $MNLJ - KLJ$. For a linear approximation to the demand curve $KLJ = 1/2 \Delta q \cdot \Delta p$.

The theory governing the estimation of cost impact on a given industry is quite simple; in practice, however, it is much more difficult. The difficulty arises in attempting to estimate the response of industry to the increased production costs that come with the cost of compliance with the proposed standard (or the increment between the existing and the proposed standard).

3.3 Double Counting -- Property Values and Health Damages?

I follow Fisher's argument (pp. 15-17), but I question his intuitive reasoning for recommending these be added together. For example, should we add the monetized health damages due to air pollution on residents (living close to freeways) to their property value reductions?

In most cases, and Fisher notes this, care must be taken to avoid double counting. In meeting a new occupational health standard, for example, an employer can expect to experience a reduction in his workmen's compensation and other insurance payments. He may also be able to secure labor at a lower cost as workers perceive the reduced hazards of working for him. These reduced payments are a reflection of the benefits of the new standard. As such, it would be improper to treat the value of reduced hazards as a benefit and also subtract these savings from the firm's cost function when computing the cost of compliance. Such treatment would result in a double counting of the benefits. I would like to see the conceptual basis behind Fisher's intuitive judgment, here. (See, also, further remarks, pp. 48-9, below).

3.4 Valuing Human Health and Life

Fisher, I believe, most correctly cautions against too cavalier a use of statistical and/or econometric studies relating wage rates and the probability of loss of life (pp. 7-9). From my own experience, I have attempted -- on and off -- to assess the justification of governmental regulation of occupational exposure to safety and health hazards on the basis of a theoretical argument that the unregulated labor market provides firms with inadequate incentives to reduce occupational hazards. This theoretical argument, in turn, is based upon the assertions that: (1) imperfect information causes the wage demands of workers to respond inadequately to differences in these hazards between occupation, and (2) the speed with which workers and firms adjust to new information about the hazards existing in particular work environments is inadequate.

Recently, several studies have attempted to evaluate the validity of these theoretical arguments. However, because these studies constitute merely cross-sectional analyses of relatively aggregative data sets (as Fisher also notes), they provide less than conclusive evidence about the probable magnitude of the steady state response of workers' wage demands and quit rates to perceived differences in occupational safety and health hazards and they provide no insights into the issue of the rate of response of the labor market to new information about these hazards.

One type of analysis, I believe, is (a) feasible, and (b) would significantly clarify this situation. It would involve performing a set of dynamic time-series analyses of the labor market adjustments (referring both to wage and quit rates) of both occupationally exposed workers and the firms employing these workers to identifiable increases in information about particular safety and health hazards. These analyses would be performed using a comprehensive statistical model of the labor market situation confronted by an individual firm whose production process embodies some occupational safety and/or health hazard. This statistical model, in turn, would be derived from a theoretically valid conceptual framework which incorporates appropriate representations of the optimizing behavior of both occupational exposed workers and their employers. The empirical analysis of the statistical model would be accomplished by applying established econometric techniques to a set of disaggregative data sets, focusing first on readily available data (e.g., Michigan Survey Research, Parnes, and others) or, on a prototype basis, gathering data from the files of a set of cooperating companies and labor unions. The utility of this model system for assessing policy options could then be demonstrated using a variety of policy options, including governmental, labor, and industry actions affecting job perception hazard.

We can all agree that participants in labor markets have only an imperfect estimate of the hazards attached to various jobs. The wage-hazard relation observed in the market is affected by the distribution of ignorance. At any point in time, new information may be introduced. The response of the market to new information depends upon how rapidly this information is disseminated and the rapidity with which workers respond to new information once they receive it. The question of response to new information would appear to be especially critical in those areas of hazard that are related to health rather than safety but are present, to varying degrees, in safety-related situations, particularly (for example) where a new safety-increasing technology is introduced in the industry. Often the nature of a health hazard cannot be perceived without epidemiological studies which reveal significant differences in patterns of morbidity and mortality from that of general population. For example, recent studies of asbestos workers and chemical workers have shown that relatively short durations of exposure to asbestos and vinyl chloride can have significant consequences long after the period of exposure. Without such studies, it is doubtful that anyone would have suspected this dimension of hazard. In the case of primarily safety hazards, combinations of raw and analyzed statistics*, folklore, and word-of-mouth are the sources of the hazard perceptions of workers both in and out of any industry in question.

* Government, union, industry, etc.

If workers respond rapidly once they receive new information, then there may be significant social payoff to investing in social devices that improve the dissemination of knowledge. However, if market response to information is sluggish, then a case can be made for substituting regulatory action for market reaction in order to better represent the interests of workers during what would otherwise be a long adjustment period.

While it would seem that significant numbers of research studies would have been addressed to measurements of these labor market responses, none have yet achieved the estimates of differential market responsiveness I refer to above.

My colleagues and I have sketched the outline of such a model but have not yet assembled the data base or fully articulated the model. Perhaps this is an area worthy of effort by the integrated assessment project.

3.5 On Risk Measurement

Above I have already commented about my feelings about the difficulties of meshing risk assessment methods with the more traditional cost-benefit techniques: I think the i.a. project could make a very useful contribution if it could advance the integration of these concepts a few inches or so.

After all, what is in question, here, are not the traditional benefits and costs associated with public policy, but those related to the reduction in risk of human death and/or serious debilitation. "Risk" has been defined as the*:

...potential for realization of unwanted, negative consequences of an event or combination of events to individual groups of people or to physical and biological systems....

One of the major problems facing society is how to determine acceptable levels of risks for new or existing activities, once these risks are reasonably defined. Although this problem exists for voluntary risk situations, the primary concern here is the treatment of involuntary risks imposed inequitably upon groups in society who either knowledgeably or unknowledgeably do not reap the benefits of the activity causing the risk. It is the responsibility of representative government to assure that such inequities are minimized...

A regulatory agency, involved in setting standards of acceptability for society, has the responsibility of making the required value judgments for society, but has the responsibility to do so in a procedural manner that assures that all affected parties are heard from, that expert testimony and available technical information are used to the extent possible, and that the value judgments made are done so in a visible, reportable manner for all to question and revisit, if necessary.

Many of the conceptual and implementation questions and issues about risk analysis were addressed in CONSAD's recent development of a Benefit-Cost System for Chemical Pesticides** for aiding EPA in the evaluation of regulatory decisions, and were also discussed, reviewed and evaluated in CONSAD's national workshop on risk, benefit, and cost methodological problems and issues in the field of toxic materials***. The problems of drawing inferences from laboratory testing of single or multiple species to

* W.D. Rowe, An Anatomy of Risk, EPA, Draft, December 1974, pp. 1-2.

** EPA 540/9-76-001, January 1976, prepared for the Office of Pesticide Programs.

*** CONSAD Research Corporation, Report on Risk/Benefit/Cost Workshop, Draft, prepared for EPA, 1977.

man, of measuring and evaluating tangibles and intangibles, and of combining and integrating a widely diverse range of human health and environmental impacts to provide meaningful inputs for public sector decisionmaking, are well known. I do not wish to minimize these difficulties.

3.5.1 Assessing Health Risks: Toxic Substances and the Work Environment

Health effects may well be the most difficult to assess. The introduction of a toxic substance, or other hazardous material into the work environment, for example, can result in short-term immediate human health effects and/or long-term gradual human health effects if the population is exposed to the pollutant. Below is a list of questions and issues analysts should find useful in structuring the analysis of health effects:

1. What dimension should be used for delineating the likely human health effects from exposure to a particular hazard, e.g.:
 - o Short-term versus long-term?
 - o General public versus occupational?
 - o Voluntary versus involuntary?
 - o Direct exposure versus indirect exposure?
 - o Types of illnesses induced?
2. How can the analyst determine the size of and identify the population likely to be exposed to dosages of a given level of a particular hazard?
3. How can the analyst separate the human health benefit of eliminating a particular hazard or one source of a particular hazard from the overlapping effects of a pollutant known to occur in the same environment?
4. Given that he knows that the toxicology data is deficient in many respects, can the analyst use existing data to predict the likely human health effects; that is, can he effectively estimate dosage-response rates in people from toxicology experiments?
5. How much epidemiologic data must be supplied in order to assess the likely human health effects of a given pollutant, and how can epidemiologic data be precise enough to predict effects on future populations?
6. Assuming that human health damage can be quantified in non-dollar terms (e.g., number of people incurring a certain type of injury), should the damages be then quantified in dollar terms and if so, how; in addition, what is the relative importance of short-term human health effects versus long-term human health effects and how should these differences be measured?

In addition to these conceptual problems concerning risk, there is the equally important matter -- briefly alluded to above -- of defining and estimating the subpopulations at risk in a particular work hazard situation. In work environments, as in other attempts to measure populations-at-risk, there are many difficult data collection problems, including: difficulty in obtaining corporate records; industrial and individual migration; defining the specific exposure (particularly if the industrial process has changed over the period); and changes in the levels and types of protection afforded. Recognizing the difficulties in estimating the total employment effect in a directly impacted industry, the size of the industry population that can expect a change in health status can be determined. This is necessary data to calculate the estimated benefits to imposing a standard on that industry. (Ideally, a statistical variance, given the uncertainty of the estimate, would be very useful information, also.) The benefits of imposing a standard derive from the change in the health or safety status of workers that can be

expected if the standard is met. An assessment of the expected change in health status requires a determination of the change in morbidity and mortality characteristics of the affected work population expected by imposition of the standard. Given such an assessment, an evaluation must be made of the value of achieving the predicted change in health status (see Section 3.4, above).

3.6 Specific Comments*

Fisher's paper is intentionally brief so in this Section I'd like to elaborate on a few points:

1. "The difficulty is, of course, that there are many other influences on health, which may or may not themselves be related to air pollution" (Fisher, p. 5). Not only is this true; but also in many instances, no chains of theoretical linkages between the pollutants and the observed health effects have been empirically verified.
2. "Then we might at least be able to say that a given estimate is an upper or lower bound, a useful result" (Fisher, p. 7). This is often the most useful piece of information to have when interpreting the policy significance of results.
3. "...The most vexing question in pollution demand studies is how to put a value on human life" (Fisher, p. 7). Really, Fisher means the incremental cost of premature death (see point 5, below).
4. "The relevant value, instead of being determined by analytical methods and then given to the political process, to use as it chooses in assessing and deciding on programs, is itself extracted from the political process" (Fisher, p. 7). Also, these values, being determined by third-parties, fail to reflect the willingness of the individuals at risk to bear this risk. The wrong people are determining the value of reducing the risk.
5. "A given improvement will result in, say, a decrease in the expected number of lung cancer deaths per thousand population" (Fisher, p. 8). I fail to understand why existing research focuses so heavily on excess deaths attributable to particular diseases. While, admittedly, most people would prefer quick, painless deaths to prolonged, excruciating ones, it is the timing of death -- not its cause -- that is of greater importance. Death is inevitable, but may be deferrable. Thus, I cannot understand why researchers have generally failed to examine health hazards in terms of their effects on life expectancy (i.e., expected length of life) rather than on expected cause of death.
6. Fisher's recommended techniques (property values, intercity wage differences) can be considered special cases of a general type of study, e.g., "spatially-specific price differentiation".
7. "Accordingly, A should be chosen in the first period only if its environmental cost then is less than B's by a substantial amount, which reflects the value of the new information" (Fisher, p. 15). Or, more generally, the extent to which A should be used in the first period should be a function of the magnitude of the difference between the environmental costs of A and B during the first period. Commitment to the option with irreversible consequences can, and should, be viewed in a marginal context.
8. "...Property value and health, should probably be added together, rather than viewed as alternatives. On the other hand, adding structural damage to a figure reliably estimated from a

* I have been assisted in this section by Charles Laidlaw and Fred Rueter -- although the responsibility is mine, of course.

property value study would probably represent double counting. Where a summary measure like property value is not available, damages from separate effects should, of course, be added together" (Fisher, p. 17). Could this hypothesis be tested, for example, in situations where both property value estimates and estimates of damages from all separate effects are available? Property value estimates could then be compared to the sum of all separate damage estimates, and to the sum of all separate damage estimates except health damages, to assess the extent to which health damages are reflected in property values. Conceivably, if several such situations could be studied, it might even be possible to derive some general conclusions.

CASE STUDY: RECLAMATION OF STRIP-MINED LANDS -- SOME COMMENTS

by

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Introduction

The case study on strip-mining identified three major cross impact areas related to the integrated assessment of the regulatory approach developed to implement P.L. 95-87 (SMCRA). These are cross-media impacts (air vs. water vs. land uses), cross-technology impacts (surface vs. deep) and regional impacts. In this discussion I wish to assess these cross impacts in the context of land impacts and resource development. The cross-media impact will be coal vs. land use; the cross-technology is surface vs. deep coal mining; and regional impact will be Eastern vs. Midwestern vs. Western coal development. This appraisal of the strip mining case study for integrated assessments will conclude by discussing the importance of the integrated approach to the development of national mineral resources.

Cross-Media Impacts: Land Use vs. Resource Development

An important cross-media impact is related to the development of coal resources or the preservation of land productivity and/or existing use. SMCRA has provisions covering a wide range of land uses. Surface coal mining is restricted or prohibited within the boundaries of the National Park System, the National Wildlife Refuge Systems, the National System of Trails, the National Wilderness Preservation System, and the Wild and Scenic Rivers System, on alluvial valley floors of current value to agriculture, in urban areas, etc. Perhaps the most significant land use requirement is that surface coal operators on prime farmlands return them to post-mining productivity levels equivalent to those of surrounding unmined lands of similar capabilities under equivalent levels of management. The net effect of these provisions is that tradeoffs between resource use and land use need to be made.

I would now like to consider two points: the amount of strippable coal potentially excluded by these land use provisions and the regional distribution of such exclusions. Such impacts have been examined at ANL¹ for 24 states and are based on strippable coal reserve base estimates made by the U.S. Bureau of Mines in 1975. The state figures have been aggregated from county-level data. More than 95% of the reported strippable coal reserve base was covered by the sample. Land use acreages were determined from information published by the National Park Service, by the National Forest Service and in the 1967 Conservation Needs Inventory. The four land uses examined are: prime cropland, national forests, parks and related lands, and urban and developed lands.

In one study, nationally around 50 million acres are potentially impacted. Prime cropland has the largest coverage, approximately 30 million acres and affecting approximately 11% of strippable coal reserve base tonnage. National forests impact approximately 4% of the strippable coal reserve base tonnage,

¹ Harper, J.P. and M.M. Anderson, "Public Law 95-87 Land Use Policies and Surface Coal Development, Volume I -- Analysis of Policies", (Draft) Argonne National Laboratory (1978).

while parklands impact approximately 1.5% and urban lands impact approximately 2%. Regionally, the Midwest and North Dakota are most impacted by prime cropland policies. National forest provisions mostly affect the West while the urban lands impacts are more keenly felt in the East and Midwest.

Cross-Technology Impacts: Surface vs. Deep

In this case study, a significant cross-technology impact discussed was the surface vs. deep mining issue. A number of areas were identified for future study. For example, examination of the environmental tradeoffs between the effects of deep mining (acid-mine drainage, subsidence and safety) and the effects of surface mining (surface disruption, erosion and sedimentation). However, the major tradeoffs related to this surface vs. deep mining issue are sociopolitical.

P.L. 95-87 states as one of its purposes that underground extraction of national coal resources is preferred to surface extraction. The NEP also endorses this concept and extends the mandate by encouraging development of Eastern coal resources. Encouraging Eastern coal development is an indirect endorsement of deep mining over surface because most coal resources in the East are deep. Thus, by using NEP scenarios for coal development and one proposed by the NCA, we can assess the surface disturbance impact from the NEP policies concerning coal development.

A preliminary estimation of ANL² at the regional surface and deep production and associated surface disturbance for either the NEP or the NCA, 1985 coal development approaches indicates 15% more coal (185 million tons) would be produced and 12% (11,000 acres) less surface area would be disturbed if coal development proceeds according to NCA projections (i.e., expanded Western surface development).

Regional Impacts: Eastern vs. Midwestern Coal Development

The cross-media and cross-technology impacts are strongly related to regional issues. The two coal development strategies -- the NEP or governmentally directed approach and the NCA or market directed approach -- are distinctly different in the tradeoffs proposed. The NEP approach is oriented to deep coal development in the Eastern and Midwestern sections of the country. The NCA approach is surface and Western oriented. In terms of the land use tradeoffs to be made, the NEP will most likely affect more prime cropland than the NCA approach and will call for more development in the highly urbanized areas of the country. The NCA approach will impact more Western lands which are more difficult to reclaim.

Concluding Remarks

The general cross-impact approach proposed in the case study can be extremely useful for the integrated assessment of environmental regulations and policies. The cross-media impact (coal vs. land use) will disturb each land category in each state differently. The cross-technology impacts (surface vs. deep) will affect the total disturbance of land and also alter it regionally. The regional impacts in turn are dependent upon the cross-media impacts and cross-technology impacts. Thus, this interdependence of the impacts illustrates the utility an integrated assessment approach has for the resolution of such environmental tradeoffs. However, the final resolution will heavily depend on sociopolitical decisions which will formulate the coal development and regulatory strategies for the nation (e.g., deep over surface, Eastern over Western, etc.).

² R.P. Carter, et al., "Report of The Special Committee to Study Health and Environmental Effects of Increased Coal Production", Coal Resources and Land Reclamation Group, Argonne National Laboratory (1977).

COMMENTS BY ERIC O. STORK

Visiting Professor in Technology and Public Policy
Purdue University

on a paper entitled

"A CASE STUDY ON MOBILE SOURCES OF AIR POLLUTION"

by Michael M. Simpson

at a Workshop on
Integrated Assessment for Environmental Standards

Energy and Resources Program
University of California
Berkeley, California

November 2, 1978

I only have a few minutes for this commentary. So I won't take time to beat around the bush.

In part, Simpson's paper purports to be a history of the auto emission control program. It is not a very good history, I'm afraid. Certainly not a complete history, but that would have been impossible even if all of the fifty or so pages had been devoted to history alone. But the incompleteness of the history is not what concerns me. I am concerned that some key data that are presented are just plain wrong. In addition, much of the interpretation of what happened is unrecognizable to me.

Assuming that the history of what happened is important to the thrust of an argument, then it seems important that at least the history be correct. Thus, the first thing that the author of this paper needs to do -- if history is important to his argument -- is to get the facts straight and to check out the interpretations. I'll not take the time here to point out the errors -- we can do that privately.

In part, Simpson's paper is a plea for use of economic incentives instead of across-the-board, mandatory standards. In reading the plea I got the feeling that the author genuinely felt that his ideas were not only good but also rather novel -- there was little recognition in the paper that the author was stomping through well-worn paths.

The issue of economic compliance techniques vs. pass/fail standards has been the subject of conference after conference, administrative directive after administrative directive, Congressional proposals, academic papers, and what have you, for many years. In the field of auto emissions, use of economic incentives has not come to pass -- but not for lack of consideration.

The extensive consideration of the economic approach in the past makes it rather easy to point out the flaws in the simplistic subsidy and penalty suggestions that are tossed out in the paper as possible solutions. For example, it is naive to suggest -- as the author suggests -- that by increasing the price of new cars one makes only the rich pay the cost of emission control, and protects the poor who typically own the older cars. Anyone who has bought a used car recently should realize that the value of used cars is to a large degree a function of the cost of new cars.

It is equally naive to believe that if there were no price disadvantage to do so, people would buy clean cars in favor of dirty cars; as a matter of fact, because of the way in which auto emission controls tend to be perceived, many people would pay a good deal more to buy cars without emission controls if they had that choice. That phenomenon alone, by the way, would be enough to do in the so-called two-car

strategy suggested in the paper; that approach may be an economist's dream, but it would turn out to be an administrator's nightmare.

In part, Simpson's paper is critical of what has been done to control auto emissions because of the single-minded, narrow focus of the past efforts. The paper is concerned about the failure to have considered what the authors refer to as cross-effects and tradeoffs. While there is validity in describing the past approach as having been narrowly focused, the paper is devoid of discussion of why so narrow a focus was pursued. For good or ill, there were reasons for doing it that way. More importantly, the paper fails to explain what social harm -- if any -- has been done by the narrowly-focused approach that it condemns. I do not, of course, propose to defend as perfect the details of every decision of which I was a part. But I would have to have a detailed exposition of the harm that we caused to become concerned that the way in which we approached the problem was not appropriate. Simply describing our approach as having been imprecise and inelegant doesn't shake me up at all.

Finally, Simpson's paper is shot through with what can only be described as motherhood dicta. "Quantification of air pollution damage should be performed, to a better degree than in the past" (p. 35). "In short, it is recommended that future health studies be performed to produce data of greater accuracy and utility than those of the past" (p. 44). "Auto testing procedures for emission certification (should) more closely conform to real driving conditions" (p. 44). "Much more extensive field surveillance programs should be carried out by the EPA on a regular basis" (p. 46). "A systems analysis approach would probably suggest more than retrofitting in-use autos with emission control devices" (p. 47). "The public should be more intimately and directly involved in the decisionmaking process" (p. 53).

My God! I cannot help but wonder whether the author has even the slightest idea of what he is talking about. Has he ever tried to quantify the damage of air pollution? Has he ever tried to perform health studies that provide better data? Has he any idea of what it takes even to assess the degree to which test procedures conform with the real world, much less to change them to better conform to that world? Has he any notion of the cost of field surveillance, or of the difficulty of finding contractors competent to do the work? Has he not even looked at what has happened when retrofit programs or transportation control programs were tried? Has he ever tried "to involve the public intimately and directly in decisionmaking", whatever that may mean?

Of course he has not. That's OK. The author is a thinker, not a doer. But what is not OK is that in the paper the author gives no evidence of even having looked closely at the attempts that have been made to do all of the things that he urges be done, nor at the obstacles that have been encountered. Without at least showing that he has done his homework, the author simply cannot expect to be taken seriously in what he recommends.

The only generally constructive statement (not a new idea but at least a valid one) that I found in the paper was the statement that, "In the future, it will become increasingly more important to try to determine how much we want to spend to clean up the air a little bit more" (p. 47). That is indeed the heart of the issue, rather than cross-effects, tradeoffs, and other analytical elegance. The cost of the pursuit of social goals is what is really at stake. The rest of my comments today will address that issue.

I despair of achieving a better balance among cost and benefits through calling for increasingly more sophisticated cost-benefit analysis. First of all, we are not likely to get very much better data on health effects, or on damage functions, and so forth than we already have. Certainly we are not likely to get better data any time soon, or get it at low cost. The same asymptotic effect that makes the last bit of environmental clean-up proportionally so expensive applies also to improving the quality of data.

Secondly, no amount of analytical data alone can really help us make better decisions so long as the goal that is being pursued is by definition incapable of being achieved. Let me explain what I mean by that. The Congress has told the EPA Administrator to establish ambient air quality standards -- and then to make sure that those standards are met. The Congress has told EPA to set ambient air quality

standards at a level that will protect the public health from any known or anticipated adverse effects associated with air pollutants, with an adequate margin of safety.

In other words, the Congress has mandated a goal of not just zero social risk, but actually less than zero risk. That's a tough goal to pursue programmatically. Let's look at what it means. In a rather dramatic but not incorrect way, it means that, for example, carbon monoxide from cars must be controlled to a degree at which the sickest cardiac victim who is still walking around could, on the second worst recorded inversion day in Chicago, spend eight hours at the busiest street corner in Chicago, without suffering any ill effects from carbon monoxide. Expressed that way, our national goal tends to make me uncomfortable.

Air pollution goals are not unique in this respect. Water pollution goals are similarly idealized, as are auto safety goals, Food and Drug goals, and OSHA goals. In all these cases, the Congress has told the administrative agencies to pursue an ideal, and has done so without providing guidance as to acceptable social risk and acceptable economic costs.

It is obvious that such goals will never be fully reached. Yet one cannot argue that the pursuit of such goals is inherently a bad thing. As a nation we have a right to try to come as close to achieving such goals as we reasonably can. The key word is reasonably. How does one deal with that?

Certainly we have not dealt well with reasonableness through our attempts to come up with more and more data that would quantify the benefits. In fact, several years ago in EPA we abandoned the effort even to make cost-benefit analyses, in favor of making cost-effectiveness analyses. In other words, we accepted as given certain goals (like achieving air quality standards) and tried to find the most cost effective way of achieving the goal.

Cost-effectiveness analysis, I believe, holds more promise than cost-benefit analysis. It is possible, in a fairly crude but nevertheless effective way, to predict about what compliance with an additional regulatory requirement would cost. In other words, one can estimate pretty well how much additional monies would have to be expended by industry and the public to comply with a new regulatory requirement. With such data in hand, choices can be made as to which abatement approach is most cost-effective, as for example in terms of eliminating tons of pollutants per dollar per year.

But there has been something missing in this analytical approach. Something very important. Regulators today still have no real incentive for concern with compliance costs. After all, it is not their money that is being spent -- but their failure to impose new requirements would mean that they might be criticized for not doing their jobs to protect the public.

Thus, to achieve the one goal in Simpson's paper that I picked out as valid and important, namely, 'to find a rational way to determine how much we want to spend to clean up the air a little bit more -- or to achieve some other social goal -- to do that we need to change the system. We need to make the regulator care not just about the relative cost of his regulatory options in any one area; we need to make him care very much about what it will cost in the aggregate to comply with all of his regulatory requirements.

How to go about changing the system to do that? The recently discussed concept of a regulatory budget may be one useful approach. Under a regulatory budget system, the government would decide periodically, at a macroeconomic level, how much additional cost it is willing to impose on the national economy during a future period of time for the purpose of improving the quality of life -- i.e., for further progress in clean air, clean water, auto safety, clean food and drugs, workplace safety, and so on. Through a process of budget request and allocation not unlike the present processes for the administrative expenses budget, a total amount would be decided upon. That total then would be allocated among the various agencies that have regulatory missions to pursue. For example, an agency like EPA or OSHA would get some amount of authorization for imposing additional compliance costs -- in all likelihood an amount less than the agency asked for -- and the Administrator of that agency would be free to impose new regulatory requirements in all of his areas of responsibility up to but not exceeding the limit of

incremental compliance cost authorized for his agency. Such an approach would apply to every health and safety regulatory agency.

Such an approach would not solve all problems, nor would it necessarily assure the use of all of the analytical tools touted in the paper we are discussing. But such an approach might stimulate at least partial use of the tools that have been urged upon us in this paper. For the first time it would highlight the cost of pursuing the social goals. A regulatory budget approach would certainly cause any regulatory administrator to look much more carefully than he now needs to look at the costs of the new requirements that he considers imposing, and would cause him to weigh alternatives and tradeoffs that now are never even considered.

For example, the EPA Administrator would have to weigh imposing a new auto tailpipe requirement against possible new toxic substance requirements against a new water requirement, and so forth. To help make such choices, the Administrator might even use some of the analytical tools that have been suggested in Simpson's paper. Some of these tools may even be useful. But we'll never know whether they can be useful unless we give the regulators a real incentive to try to use them to make their decisions in a more balanced way than they have been making them in the past.

A regulatory budget would, admittedly, be a meat-ax approach. A meat-ax tends to offend those who feel that the world should be more rational. But from the standpoint of many years' experience, I'm convinced that only a meat-ax approach has a chance of success when it comes to making significant change in the way in which institutions do things. I would be hard to persuade that a meat-ax is an inappropriate tool just because it is imprecise and inelegant. After all, a meat-ax approach was highly effective for the EPA in getting the auto industry to change its way of building cars -- and the cars that the industry is building today are much better from the standpoint of clean air and fuel economy than were the cars before we swung our meat-ax. Whether or not you like the way we did it, you can't deny that we achieved a whole lot of what we set out to do.

Perhaps it is time to apply such a meat-ax to the process of setting regulations in the health and safety field. Sometimes there is much wisdom in old stories. The one I have in mind is one that I'm sure you have all heard. So I'll quote only the punch line: You can successfully get a mule to pay attention to instructions whispered into his ear only after you've hit him over the head a couple of times with a two-by-four.

Attendees at the Workshop on
Integrated Assessment for Environmental Standards
November 2-3, 1978.

UCB/LBL Study Team

Mr. Charles Blanchard
Dr. Anthony Fisher
Dr. John Harte
Dr. John Holdren
Ms. Veronica Kun
Mr. Gregory Morris
Mr. Michael Simpson
Ms. Kathy Tomnessen

UCB/LBL Observers

Dr. Elton Cairns
Dr. Mark Christensen
Mr. Irving Mintzer
Mr. Kent Anderson
Dr. Bart McGuire

DOE Office of Technology Impacts

Dr. Richard Ball
Dr. Joseph Coleman
Dr. Peter House
Mr. George Kelly
Dr. Roger Shull
Mr. Ted Williams

Invited Discussants

Dr. Robert Curry, University of Montana
Dr. Stanley Greenfield, Teknekron, Inc.
Mr. Gerald Hansler, Delaware River Basin Commission
Dr. Jerome Harper, Argonne National Laboratory
Dr. James Krier, Stanford University
Dr. Paul Portney, University of California, Berkeley
Mr. James Russell, DoE Region IX Office
Dr. Wilbur Steger, CONSAD Research Corp.
Dr. Eric Stork, Purdue University
Dr. Weston Vivian, University of Michigan
Dr. Michael Yokell, Solar Energy Research Institute

Other

Dr. Steve Ballou, Argonne National Laboratory
Mr. Mark Pisano, Southern California Association of Governments

APPENDIX B

PROCEEDINGS OF A WORKSHOP ON NATIONAL ECOLOGICAL ASSESSMENT

Savannah, Georgia

January 10-12, 1979

ANL/AA-15

Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

January 1980

Sponsored by
Assistant Secretary for Environment
U.S. Department of Energy

TABLE OF CONTENTS

	<u>Page</u>
EXECUTIVE SUMMARY	B-5
ABSTRACT	B-15
1 INTRODUCTION	B-15
2 ECOLOGICAL PROCESSES	B-19
2.1 Significance of Process Impacts	B-19
2.2 Consumption or Alteration of Water Resources	B-19
2.3 Airborne Pollutants	B-22
2.4 Land-Use Changes Due to Energy Technologies	B-26
2.5 Assessment on a National Scale	B-26
3 POPULATIONS	B-28
3.1 Rare Species	B-28
3.2 Endangered Species	B-29
3.3 Dominant Species	B-30
3.4 Indicator Species	B-33
3.5 Keystone Species	B-35
3.6 The Spatial Scale of Population Analysis	B-36
4 ECOSYSTEMS	B-38
4.1 Spatial Classification of Ecosystems	B-38
4.2 Regulation of Structure, Composition, and Function of Ecosystems	B-41
4.3 Pattern of Normal Stress and Alteration by Man	B-41
4.4 Regulation of Biochemical Cycling	B-41
4.5 Ecosystem Interaction	B-45
4.6 Ecosystem Resiliency and Health	B-46
4.7 Patch Mosaic Properties: Colonization	B-46
4.8 Spatial and Temporal Scale Considerations Associated with Dynamic Oscillation and Cycling Regulation within Ecosystems	B-50
REFERENCES	B-52
TASK GROUPS FOR THE NATIONAL ECOLOGICAL ASSESSMENT WORKSHOP	B-54
WORKSHOP PARTICIPANTS	B-55

LIST OF FIGURES

<u>No.</u>	<u>Page</u>
1.1 Pollutant-Ecosystem Interactions	B-16
3.1 Reliability of Endangered Species Data as a Function of Spatial Scale	B-31
3.2 Value of Population Impact Analysis for Ecological Assessments at Different Spatial Scales	B-37

FOREWORD

The Energy and Environmental Systems Division at Argonne National Laboratory is evaluating, through its Midwest Regional Assessment Program, the impacts and consequences associated with alternative energy options. As part of this overall effort, analytical procedures for conducting these analyses are being developed at ANL and elsewhere. This document reports the results of a three-day workshop that addressed issues and possible approaches to conducting energy-related ecological assessments. Additional studies related to the development of ecological methods for evaluating energy technologies are continuing at Argonne.

ACKNOWLEDGMENTS

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TABLE OF CONTENTS

	<u>Page</u>
EXECUTIVE SUMMARY	B- 5
ABSTRACT.	B-15
1 INTRODUCTION	B-15
2 ECOLOGICAL PROCESSES	B-19
2.1 Significance of Process Impacts	B-19
2.2 Consumption or Alteration of Water Resources.	B-19
2.3 Airborne Pollutants	B-22
2.4 Land-Use Changes Due to Energy Technologies	B-26
2.5 Assessment on a National Scale.	B-26
3 POPULATIONS.	B-28
3.1 Rare Species.	B-28
3.2 Endangered Species.	B-29
3.3 Dominant Species.	B-30
3.4 Indicator Species	B-33
3.5 Keystone Species.	B-35
3.6 The Spatial Scale of Population Analysis.	B-36
4 ECOSYSTEMS	B-38
4.1 Spatial Classification of Ecosystems.	B-38
4.2 Regulation of Structure, Composition, and Function of Ecosystems	B-41
4.3 Pattern of Normal Stress and Alteration by Man.	B-41
4.4 Regulation of Biochemical Cycling	B-41
4.5 Ecosystem Interaction	B-45
4.6 Ecosystem Resiliency and Health	B-46
4.7 Patch Mosaic Properties: Colonization.	B-46
4.8 Spatial and Temporal Scale Considerations Associated with Dynamic Oscillation and Cycling Regulation within Ecosystems. . .	B-50
REFERENCES	B-52
TASK GROUPS FOR THE NATIONAL ECOLOGICAL ASSESSMENT WORKSHOP	B-54
WORKSHOP PARTICIPANTS	B-55

LIST OF FIGURES

<u>No.</u>	<u>Page</u>
1.1 Pollutant-Ecosystem Interactions	B-16
3.1 Reliability of Endangered Species Data as a Function of Spatial Scale	B-31
3.2 Value of Population Impact Analysis for Ecological Assessments at Different Spatial Scales.	B-37

EXECUTIVE SUMMARY

In cooperation with the U.S. Department of Energy, Argonne National Laboratory conducted a workshop in January 1979 to identify the concerns, methods, and problems of performing non-site-specific ecological assessments of energy development impacts. Thirty-nine ecologists, social scientists and policy makers, representing universities, industries, government agencies, and the national laboratories, met informally to address the following objectives:

1. To identify the ecological concerns that should be addressed in a non-site-specific assessment of energy technology.
2. To establish which concerns can be addressed in near-term, energy-related assessments with existing methods and/or data bases, and to provide guidelines on how to address these concerns.
3. To establish which concerns require additional methods and/or data-base development for future non-site-specific assessments.
4. To characterize the problems associated with assessments of different spatial scales.
5. To characterize the problems of predicting ecological impacts for energy supply-demand scenarios 30 years in the future.

The workshop Steering Committee felt that a broad coverage of ecological concerns could be achieved by creating three task groups whose focus would be ecological processes, populations of organisms, and ecosystems. Each group was asked to prepare a written discussion of its conclusions, and all of the participants contributed to the texts consolidated in this volume.

The three task groups took different approaches in identifying the major ecological concerns. The Process Group focused on several key ecological processes and how specific energy-related residuals affect those processes. The Populations Group identified "special" species and discussed how each would be used in judging impacts. The Ecosystems Group identified ecosystem characteristics that regulate ecosystem structure, composition, and function. Each group's responses to the workshop objectives are summarized below.

PROCESS TASK GROUP

Objective 1: Identify the ecological concerns that should be addressed in a non-site-specific energy technology assessment.

- A. Primary and secondary productivity: Changes in productivity of an organism or system may affect the health, vigor, and resiliency of the system as well as the number of organisms available for harvesting or for export to other systems. Thus, changes in productivity of many systems can have direct economic consequences.

- B. Cycling of elements, that is, the movement of nutrients, water, and inorganic chemicals--including radionuclides, heavy metals, and toxic substances--through and between ecosystems. The cycling of toxic materials may adversely affect plants, animals, and humans. Changes in the natural cycling of nutrients and other essential elements may affect productivity.
- C. Succession, that is, the process of ecosystem development responsible for patterns and rates of recovery following disturbance. If natural patterns and rates of ecosystem recovery can be predicted, the ecosystem may be managed to mitigate damage and enhance recovery from energy technology impacts.
- D. The important issues identified in dealing with these concerns were:
 - 1. Long- and short-term changes in productivity.
 - 2. Changes in energy flow (trophic dynamics).
 - 3. Changes in soil fertility.
 - 4. Effects on adaptability and resiliency of systems (ability to tolerate and recover from perturbations).
 - 5. Changes in the rates and timing of biological phenomena such as growth rate, maturation time, and mating periods.

Objective 2: Establish which concerns can be addressed for near-term, energy-related assessments with existing methods and data bases and provide guidelines on how to address these concerns.

- A. Many, if not most, energy activities may lead to effects on productivity through changes in land use or hydrological regimes or by releasing harmful residuals to the air or water. Most assessments of impacts on these processes will be qualitative at this time although they may depend on the quantitative predictions of hydrological, air transport, erosion, and other models.
- B. Changes in productivity can be predicted quantitatively only in a few cases.
 - 1. Several water transport models that determine changes in primary productivity in aquatic systems have been developed.
 - 2. The effect of a given ambient or transient level of sulfur dioxide on growth and productivity of soybeans can be estimated, roughly, within a factor of two, although atmospheric models may not be advanced enough to give the necessary data.

- C. Extraction of fossil fuels may result in a retrogression of succession, short-term reduction of productivity, and an opening of element cycles. Methodologies to assess changes in these processes are well developed.

Objective 3: Establish which concerns require additional methods and data base development for future non-site-specific assessments.

- A. In most cases, models (e.g., hydrological models and erosion and sedimentation models) are available for quantifying the changes in the abiotic environment. Additional work required includes:

1. Continued development of atmospheric models to predict peak and mean concentrations of SO₂ and other potentially damaging pollutants in the vicinity of point sources of air pollution.
2. Clarification of how acidic substances are formed in the atmosphere and development of methodologies to assess ecological effects of acidic deposition.
3. Projections of regional climatic changes due to increased atmospheric carbon dioxide.

- B. The quantitative prediction of ecological changes also requires the following additional work:

1. Relate the changes in aquatic parameters to primary and secondary production.
2. Develop algorithms for predicting reductions in crop yields or in primary productivity of forests or other natural ecosystems due to exposure to SO₂, ozone, or other pollutants.
3. Clarify the effects of acid rain on aquatic and terrestrial systems. Much of the present data and many of the conclusions are ambiguous, controversial, or incomplete. In addition, develop methods to define the magnitude of the potential acid-rain effects and to determine their geographic distribution.

Objective 4: Characterize the problems associated with assessments of different spatial scales. For instance, describe the variation in resolution as the geographical scale is broadened from a county level of analysis to a subregional or regional level of analysis.

- A. Some problems are not important indicators at a regional scale. For example, the aquatic cycling of minerals in streams and small lakes is not an important regional indicator because materials can be recycled many times as they are transported downstream.

- B. Estimates of impacts at larger scales will be difficult. For example, the measurement of trophic dynamics at a regional scale is almost impossible, and the estimation of changes in productivity or yield on a regional or national scale will be difficult.

Objective 5: Characterize the problems of predicting ecological impacts for energy supply-demand scenarios 30 years in the future.

- A. The magnitude of uncertainties involved makes the prediction of impacts 30 years in the future difficult.

POPULATIONS TASK GROUP

Objective 1: Identify the ecological concerns that should be addressed in a non-site-specific energy technology assessment.

- A. Five kinds of species should be considered in an assessment of impact on populations:

1. Rare species. These species are not necessarily endangered. They frequently appear as low-density populations, relict populations, populations at the extreme of their range, or populations occupying isolated habitats. These species may be more susceptible to damage from perturbation than other more common species in the community.
2. Endangered species. Such species are either listed by the federal Office of Endangered Species or by state offices as endangered or threatened, or they are proposed for inclusion in the federal list. Endangered species are protected by a detailed and carefully defined set of regulations. Their value is not a matter of debate since it has been established by law. In addition, they have many or all of the attributes of the "rare" species discussed above.
3. Keystone species. These species play a critical role in the ecosystem. They act to stabilize the physical environment or biotic community or play a central role in nutrient cycling or food chains. Major ecosystem changes or fluctuations may occur if the productivity or numbers of keystone species are reduced.
4. Dominant species. These species contain numerous organisms, account for a major proportion of the biomass, or are major pathways through which energy, materials, and/or money flow. Dominant species are major regulators of ecosystems (may be crucial in determining pathways of energy and nutrients), and changes in these dominant populations may have major implications for system dynamics. They may

determine the resiliency of the system to perturbations and the restoration potential of ecosystems.

5. Indicator species. These species can be used to quickly identify significant changes in, or continuation of, a specified condition. Changes in populations of indicator species may reflect changes in the health, vigor, and successional status of a community.

B. For each kind of species, the important issues for ecological assessments included:

1. Activities that affect the quality or quantity of habitats.
2. Homeostatic mechanisms that indicate the stability and resiliency of a population.
3. Critical population level necessary for survival.
4. Biochemical and physiological changes that may lead to secondary effects in the population.
5. Distribution of populations within the community.
6. The reversibility of an impact on the population.

Objective 2: Establish which concerns can be addressed for near-term energy-related assessments with existing methods and data bases, and provide guidelines on how to address these concerns.

A. Dominant and endangered species have the most extensive data bases and can be addressed now.

1. Endangered species. The most comprehensive data sources (range and biology) are in the files of the Office of Endangered Species in Washington, D.C., but these are not readily accessible, standardized, or computerized. The computer files at Brookhaven National Laboratory contain taxonomic, status, and range information but no biological information (see below). The computerized Sensitive Wildlife Information System (SWIS) of the U.S. Fish and Wildlife Service includes more detailed information but on fewer species than the other sources. Various states have collected endangered species information, and some of it is computerized.
2. Dominant species. Numerous and accessible (some computerized) sources of distribution data exist. These include published distribution maps, U.S. Forest Service files, and museum files. Productivity and growth data for plants are available from the U.S. Agriculture Report Service and from timber inventories. Productivity and growth data for animals are available from the U.S. Fish and Wildlife Service and from individual studies.

Objective 3: Establish which concerns require additional methods and data-base development for future non-site-specific assessments.

- A. Distributional data on rare, keystone, and indicator species are needed.
 - 1. Local studies can supply considerable amounts of information. However, data from various sources have not been standardized or gathered into a state, regional, or national file. In addition, local information is not available from all geographic areas. These species should be considered in local assessments as well as in non-site-specific assessments of regional or national scale, although the latter require much more time than do local assessments.
 - 2. Biological information such as productivity, population size, minimum habitat requirements, sensitivities to residuals, management potential, and other specialized information must be added to the distributional data in existing files.
- B. Better classifications of species status must be developed. For example, standard definitions of rare, keystone, and indicator species are needed.
- C. The following are specific problems of data collection and analysis that require attention.
 - 1. Rare species. Existing data must be assembled and integrated to produce summaries of rare species as well as isolated and unique ecosystems.
 - 2. Endangered species. Biological information should be added to data systems like Brookhaven's and should include information on the factors critical to the immediate survival and recovery of endangered species and on the types of impacts to which these species might be particularly susceptible. The Sensitive Wildlife Information System, which contains some of this type of information, should be expanded.
 - 3. Dominant species. More data on animal species are needed. An especially useful task would be to relate animal populations to specific, identifiable habitats, and additional information on productivity and growth would be valuable.
 - 4. Keystone species. Identification of keystone species in complex systems is difficult, and their effects on ecosystems should be interpreted by individuals with expertise in the biology of the region. Many examples of keystone species are known, but such information should be gathered into a standardized data base.

5. Indicator species. Health and vigor indicators are still being identified.

Objective 4: Characterize the problems associated with assessments of different spatial scales. For instance, describe the variation in resolution as the geographical scale is broadened from a county level of analysis to a subregional or regional level of analysis.

- A. Data reliability is the major concern arising out of decisions about level of analysis. The smaller the area that is being considered, the more certain will be any statement of likelihood of impact.

Objective 5: Characterize the problems of predicting ecological impacts for energy supply-demand scenarios 30 years in the future.

- A. Data quickly become obsolete. It may be hard to predict accurately what flora or fauna will be present in a given county 30 years in the future because weather, economic conditions, technological advances, social changes, disease, and many other factors may intervene to change the distribution and size of the population of interest.

ECOSYSTEMS GROUP

Objective 1: Identify the ecological concerns that should be addressed in a non-site-specific energy technology assessment.

- A. An ecosystem is defined as a complex of biotic and abiotic variables that form a functional unit.
- B. The major concerns in the study of ecosystems are as follows.
 - 1. Resource and species interactions within and among ecosystems or ecosystem patches.
 - 2. The "normal" perturbations or stresses that maintain ecosystems.
- C. The following are ecosystem characteristics that are important in addressing the concerns just listed.
 - 1. Ecosystem structure, composition, and function. Energy development may have an impact on these aspects of an ecosystem. Specifically, the effects of energy development and its consequent residuals on the diversity, number of trophic levels, and productivity of ecosystems should be examined. Energy-related activities may create new habitats and introduce new species, eliminating or weakening existing species, and making the ecosystem vulnerable to invasion by new species.

2. Frequency and pattern of normal and induced perturbations. Ecosystems are adapted to a particular set of perturbations that may or may not occur regularly. The system may depend on this perturbation regime to maintain species diversity, provide nutrients, reduce populations by eliminating diseased or injured individuals, or permit reproduction. An increase in either the frequency or magnitude of the disturbance or its elimination may significantly alter the ecosystem.
3. Regulation of biochemical cycling. Individual processes and activities within one part of the ecosystem are controlled and limited by the rates of flow (cycling) of material and energy between the separate elements or trophic niches of the system. Therefore, a direct impact on one component of the ecosystem may lead to indirect impacts on other components.
4. Ecosystem interactions. Because materials and species are exchanged between ecosystems, the destruction or perturbation of one ecosystem can affect adjacent ecosystems.
5. Ecosystem resiliency and health. The response of a system to stress and its potential for recovery are important aspects of energy-development impact assessment. Impacts may or may not be permanent, but nonresilient or unhealthy ecosystems may be permanently changed by the impacts of energy-related activities.
6. Patch-mosaic properties. The patch mosaic of an ecosystem is the structure of organism assemblages in the system. Patch mosaics are perpetuated by environmental heterogeneity and by the spatial-temporal attributes of perturbations. Important patch-mosaic properties include the size and species composition of patches, their location in space and along environmental gradients, and the stability of patch configurations.

Regional coexistence of species is based on colonization potential, inter-specific competition, and species extinction rates in patches. Changes in the perturbation regime that maintains the patch mosaic may lead to changes in the diversity of the regional ecosystem.

Objective 2: Establish which concerns can be addressed for near-term energy-related assessments using existing methods and data bases, and provide guidelines on how to address these concerns.

A. The evaluation of impacts on ecosystems requires a knowledge of the interactions within and between ecosystems and of the factors responsible for maintaining these relationships.

1. These data are available for only a limited number of terrestrial and aquatic systems. Models for assessing effects on the structure, composition, and function of a limited number of systems have been developed.
2. There are a number of tested models that focus on rates of mass transfer in aquatic systems. Necessary inputs typically include data on water movement, water quality parameters, primary producers (principally algal components), benthic algae, detritus, herbivores, and carnivores. Ecosystem changes due to changes in biochemical cycling could be assessed for systems for which this information exists.
3. Data bases that show landscape patterns in limited areas are available for the assessment of impacts on patch-mosaic properties. The principles of island biogeography can be used in such assessments to determine the direction of energy-related impacts.

B. The following methods are suggested for the study of energy-related impacts on energy systems.

1. Prepare a three-dimensional "conflict matrix" with different energy technologies on one axis, Bailey's ecoregions on another, and ecosystem types (e.g., aquatic, terrestrial, and transition) on the third.
2. To assess how an impact will be transmitted through a system:
 - a. Identify the limiting factor(s) (e.g., nutrient availability) in energy/material flows within the system; direct insults to this factor are likely to produce a more significant impact.
 - b. Trace the total flow of materials throughout the system. This may produce valuable insights into the direct impacts of changes in external supply rate and into the magnitude and rate of transmission of the resulting ecosystem-wide impact or response.

Objective 3: Establish which concerns require additional methods and data base development for future non-site specific assessments.

A. Additional research will yield more models that are dynamic and detailed representations of specific ecosystems, but identification of systems that can be used to represent a wider variety of systems would be more useful.

- B. A classification system resulting in standard terminology and definitions is urgently needed.
- C. Human alteration of perturbation cycles must be documented as exhaustively as possible.
- D. Models for terrestrial systems similar to existing aquatic models must be developed.
- E. Expand basic research on ecosystem geochemical responses to energy residuals; develop more complete models of soil uptake, weathering, and leaching processes; and validate and synthesize the results of the models.
- F. Develop procedures to determine the health and resiliency of an ecosystem, possibly in terms of its energy flow, materials cycling, species diversity, community structure, stability, and productivity.
- G. Develop data bases that show landscape patterns for a broader area, and develop methods for describing existing patch dynamics at the county level.

Objective 4: Characterize the problems associated with assessments of different spatial scale. For instance, describe the variation in resolution as the geographical scale is broadened from a county level of analysis to a subregional or regional level of analysis.

- A. Ecosystems (i.e., "landscape units") can be delimited at a variety of geographical scales, e.g., "ecosystem," "watershed," "region," "ecoregion," and "continent." Ecosystem concerns can be addressed at different levels of these spatial scales.

Objective 5: Characterize the problems of predicting ecological impacts for energy supply-demand scenarios 30 years in the future.

- A. There are differences in impact duration between aquatic (short duration) and terrestrial (long duration) systems.
- B. Interventions in the geochemical cycle may cause changes that are cumulative and that may be serious over a period of 50-200 years although almost undetectable within a single year or even five years.

PROCEEDINGS OF THE NATIONAL ECOLOGICAL
ASSESSMENT WORKSHOP

S.W. Ballou and K.E. Robeck, editors

ABSTRACT

Methods for evaluating the potential for ecological impacts resulting from the deployment of conventional and nonconventional energy systems are not yet well developed. The varying spatial and temporal scales often used in these assessments complicate the ecological analyses. This report presents the results of a three-day workshop to which ecologists and energy decision makers were invited in order to address these problems. The goals of the meeting were: (1) to discuss and identify the ecological concerns that should be addressed in energy technology assessments, (2) to establish which concerns can be adequately addressed with current knowledge and methods, (3) to suggest additional methods and data bases that might be developed, and (4) to address the temporal and spatial scale problems encountered in energy technology assessments. The discussions focused on three areas: ecological processes, populations of organisms, and ecosystems. The results of the workshop provide a framework for the continuing development of ecological assessment methods.

1 INTRODUCTION

Federal agencies are becoming increasingly aware of the need to incorporate sound environmental assessments into their planning and decision making. This awareness is especially acute in agencies responsible for providing direction for this country's energy development. Energy needs must be met, but the adverse or beneficial impacts of conventional and nonconventional energy systems are not well understood.

Environmental assessments are often complicated by the varying spatial and temporal scales used. Energy policy decisions are frequently based on alternative energy scenarios that project technology mixes and energy development 20 or 30 years in the future, but projected energy or industrial facilities are seldom sited in more detail than a county level, thereby decreasing the accuracy of the impact analysis. The reliability of many analyses, e.g., ecological, socioeconomic, or water quality, decreases as the spatial and temporal scales broaden.

Substantial effort has been directed toward identifying and quantifying the environmental impacts of energy-related activities. Quantification of impacts depends on developing a sound data base. In many cases, such quantification has been achieved for specific kinds of impacts, but not, however, for the evaluation of the ecological impacts of energy activities. Consideration of ecological impacts has been hampered by the complexity of natural

systems and the lack of adequate data bases on direct dose-response effects or on multidimensional effects such as predator/competitor responses. The release of substances into the environment, for instance, can affect biological communities in a number of ways from acute injury to subtle community effects. The pathways shown in Fig. 1.1 represent several levels of biological effects that could result from the release of specific pollutants. These effects are: (1) physiological effects, (2) effects on populations, and (3) effects on the biological community as a result of impacts on a target population or due to secondary effects on predator or competitor populations. Ecological assessments typically address one or more of these levels.

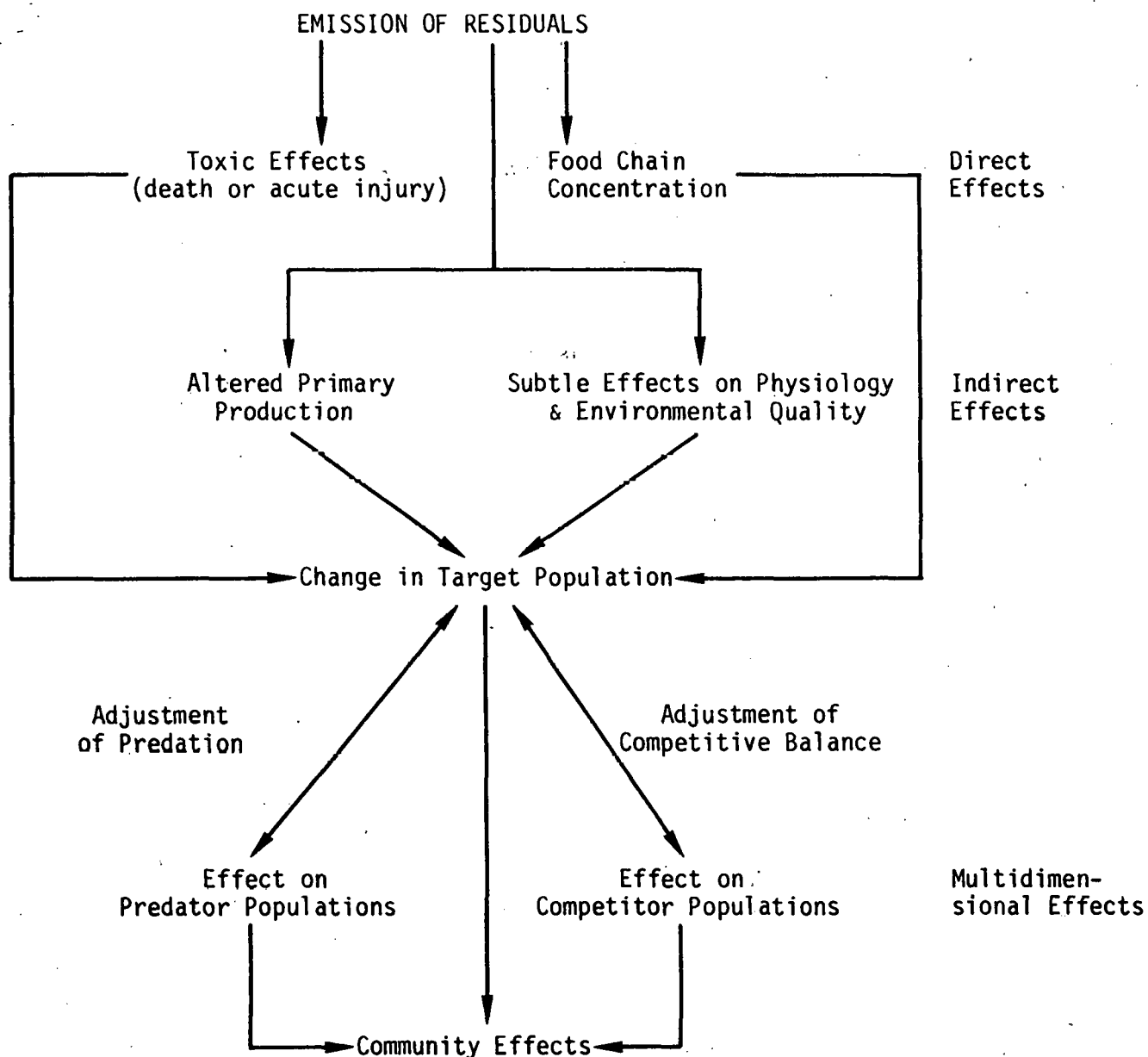


Fig. 1.1 Pollutant-Ecosystem Interactions

A recent workshop, sponsored by the Department of Energy (DOE), on the quantification of environmental damage from energy activities addressed current levels of knowledge and methods for quantifying ecological responses to energy-related residuals (Moskovitz et al., 1977). The workshop emphasized direct dose-response effects of a variety of residuals on commercial and natural ecosystems. The report from that workshop is valuable because it provides state-of-the-art methods that can be utilized in conducting energy-technology assessments, and it identifies the paucity of data on which some of these methods are based. Although the workshop provided important information on how certain populations may respond to specific residuals, DOE recognized the need for a clearer understanding of community-level responses to residuals and of the kinds of impacts on ecological processes, population arrays, and ecosystem stability.

In cooperation with the U.S. Department of Energy, Argonne National Laboratory conducted a workshop in January 1979 to identify the concerns, methods, and problems of performing non-site-specific ecological assessments of energy development impacts. Thirty-nine ecologists, social scientists, and policy makers, representing universities, industries, government agencies, and the national laboratories, met informally to address the following objectives.

1. To identify the ecological concerns that should be addressed in a non-site-specific assessment of energy technology.
2. To establish which concerns can be addressed for near-term, energy-related assessments with existing methods and/or data bases, and to provide guidelines on how to address these concerns.
3. To establish which concerns require additional methods and/or data base development for future non-site-specific assessments.
4. To characterize the problems associated with assessments of different spatial scale.
5. To characterize the problems associated with prediction of ecological impacts when developing energy supply and demand scenarios 30 years in the future.

The workshop Steering Committee felt that a broad coverage of ecological concerns could be achieved by creating three task groups whose focus would be, respectively, ecological processes, populations of organisms, and ecosystems. Each group was asked to prepare, during the workshop, a written discussion of its conclusions, and all of the participants contributed to the texts consolidated in this volume.

The three task groups took different approaches in identifying the major ecological concerns. The Process Group, for instance, focused on several key ecological processes and how specific energy-related residuals affect those processes. The Populations Group identified "special" species and discussed how each would be used in judging impacts. The Ecosystems Group identified ecosystem characteristics that regulate ecosystem structure, composition, and function. These differences contributed, in part, to some variation in presentation format.

The workshop brought together ecologists and decision makers and made an initial attempt to improve the process of incorporating sound ecological information in federal decision making. These proceedings should be regarded as just one step toward the goal of a systematic ecological assessment of energy policy choices. As one reviewer pointed out, this report "is basically a document from which the workshop should have begun." In its final form, it is a background document that also points out research needs. As another reviewer pointed out, "the 'how' is missing": actual strategies for implementing the recommendations made in the workshop are not presented. This is not surprising, considering the time constraints the participants were working under. However, a workshop of this sort need only meet incremental objectives, since it may be expected that this is not the last meeting on the subject.

It has been suggested that future work should perhaps take a technology-specific approach and focus on establishing the priority of ecological concerns. This kind of work is presently proceeding at Argonne and other national laboratories. It is hoped that in the near future there will be more meetings that bring scientists and decision makers together to build on the material presented here.

2 ECOLOGICAL PROCESSES

The ecological processes of greatest concern for ecological impact assessments are productivity, cycling of elements, and succession. Energy activities may induce qualitative or quantitative changes in these processes, and measurements of such changes may be useful indicators of ecological change. However, development of quantitative indices to reflect ecological changes due to energy technologies requires additional research. The Process Task Group attempted to address the impacts on ecological processes due to energy-related resource consumption or alteration, energy-related residuals, and land-use changes or habitat modification. Because of time limitations, the task group focused on the effects on productivity and cycling of elements.

2.1 SIGNIFICANCE OF PROCESS IMPACTS

Productivity

Gains or losses in the productivity of agricultural, some forest, and some aquatic resources have direct economic consequences, but the productivity of natural or agricultural systems is also a monitor of environmental quality. The state of the environment is quantifiable in terrestrial systems according to some measures like pollution severity, but environmental quality may be difficult to interpret because many factors besides pollution influence it.

Qualitative changes in productivity, such as substitution of species or changes in the species mix, may have economic consequences but can also affect society indirectly. Perceptions of well-being and esthetics are social variables that cannot be quantified well but which need to be given weight in assessing value to society.

Cycles of Elements

Elemental cycles in both agricultural and natural systems may incorporate additions of radionuclides, heavy metals, and other toxic substances into food webs. This process has the potential for adverse health effects in both man and animals.

Productivity changes may occur because of a reduction in soil fertility due to erosion, large-scale land alterations, and leaching from acid rainfall. Some of these losses in productivity may be irreversible. Secondary toxic effects may result from release of aluminum (Al^{+++}) or other ions.

2.2 CONSUMPTION OR ALTERATION OF WATER RESOURCES

Reduction in the Quantity of Surface Water

Many energy-related activities consume water. To the extent that ground water or surface water is utilized, three primary hydrological effects may be expected: lowered water tables, reduced floodplain flooding, and lowered stream flow. The lowering of water tables will affect terrestrial, and especially riparian systems, by reducing growth rates, reducing evapotranspiration, and modifying successional patterns.

Reduced floodplain flooding curtails local sedimentation and retention of nutrients, and thus enhances the loss of soil and nutrients to downstream systems. It also reduces the quantity of leaf litter and other organic matter that normally enter streams, thereby resulting in lowered stream production by reducing littoral feeding and spawning areas.

Lowering of stream flow rates reduces the variety of local microhabitats and changes the trophodynamic patterns of the streams. By reducing the dilution and flushing capabilities, low flow rates intensify the effects of chemical pollution on productivity, nutrient cycling, and trophodynamics. Downstream, the estuaries receive less water and fewer nutrients. Salt water intrudes, and salinity gradients are sharpened, which results in reduced estuarine production, species shifts, and changes in trophodynamics. Finally, there is reduced flow of sand and sediment to the sea, less beach nourishment, and more beach erosion.

Acceptable hydrological models are available to provide quantitative predictions of the physical changes. Information on biological change is regionally available.

Alteration in Water Quality by Residuals

Several ecological effects could result from changes in water quality of streams, lakes, and estuaries due to energy installations. Increases in aquatic acidity from mining, acid rainfall, and certain effluents will lead to increased solubility of metal sulfates and nitrates. This may cause changes in mineral cycling and trophic dynamics, reductions in productivity, and possible toxicity to certain aquatic species. Increases in acidity may also lead to increased precipitation of substances such as ferric hydroxide compounds in downstream areas. These precipitates result in drastic decreases in stream productivity and simplified trophic dynamics. Some chemical discharges, such as those from western coal production, may lead to increased alkalinity; in several cases a reduction of aquatic productivity has resulted.

Heavy metals are produced by mining activities and some conversion technologies and may be toxic at high concentrations to certain aquatic organisms. This, in turn, may lead to decreased productivity and increased bioaccumulation (reduction of mineral cycling) in streams, lakes, and estuaries.

Radioactivity can be increased in aquatic ecosystems by leakage from uranium mining, nuclear power plant discharges, coal mining and combustion, and other activities. Although radioactive materials may accumulate in sediments and biota (reducing the cycling of minerals) it is unlikely that significant effects on ecological processes will be observed except in cases of excessive accidental discharges.

Energy-related activities may add organic material to aquatic ecosystems. Increases in natural organic material from runoff due to mining, from land use changes, and from effluents generally increase biological respiration in aquatic ecosystems. Low organic loading may lead to increased productivity. High organic loading may lead to anaerobic conditions (low dissolved oxygen) and reduced productivity and ultimately to a simplification of trophic dynamics. Some synthetic organic compounds, such as the phenols produced from

coal gasification processes, can cause toxicity problems for many aquatic organisms with the result of decreased productivity and changes in trophic dynamics.

Additions of inorganic nutrients, especially phosphorus, nitrate, and ammonia, may lead to increased aquatic productivity if such nutrients are naturally limited in the ecosystems. If the productivity increases are excessive, low dissolved oxygen concentrations may result, with subsequent decreases in secondary productivity (e.g., through fish kills).

Energy production could result in alteration of existing thermal regimes in aquatic environments because of discharges, withdrawal, pumping, or other activities. Two general impacts can be predicted from such disturbances:

1. Changes in the solubility of various gases [oxygen (O_2), nitrogen (N_2), etc.] and salts (carbonates in seawater), and
2. Changes in the rates and timing of biological phenomena.

In the case of altered solubility, for instance, colder water retains more dissolved oxygen (at the same pressure) than warm water, thus lessening the chance of oxygen depletion with its resulting stress on the biota. However, the deeper, colder waters in hydro-electric reservoirs may become anaerobic, and withdrawal of these waters to drive the turbines can result in oxygen-depleted water being introduced into the stream immediately below the dam. Thus, productivity can be markedly affected by changes in oxygen content, but these effects are short-lived in natural bodies of water.

The alteration of rates and timing of biological phenomena can result in far-reaching and complex consequences. For instance, discharge of a heated effluent may be sufficient to increase the rate of maturation of organism A, which is a key food item of a particular life stage of organism B. If organism A hatches and matures before it can be utilized by organism B, the productivity of organism B will be decreased. Heat also increases the metabolic processes of biota and can thus, within limits, increase productivity and nutrient cycling. Again, however, the extent of resulting effects on productivity, nutrient cycling, and trophic dynamics are usually restricted in natural aquatic ecosystems.

Direct Impact of Man-Made Structures on Aquatic Environments

The impacts of structures such as dams, spillways, intake and discharge structures, and off-shore drilling rigs include inundation of terrestrial habitats, creation of impoverished biological zones because of water fluctuations, alteration of fish movement patterns, intake of aquatic organisms into cooling systems, and impingement of fish on intake screens. These changes are very likely to alter the productivity of the associated aquatic environments but the net change is not readily predictable.

Assessment of Changes in Aquatic Ecological Processes

Primary productivity of algae and aquatic vascular plants is readily measurable in all aquatic environments. However, secondary productivity, involving fish, zooplankton and benthic animals, is not as readily measured. At this level, it is often only possible to measure static standing stock (biomass). On a regional scale, aquatic productivity can only be ascertained by summing measurements from different environments. For example, productivity in the littoral zone on the margin of lakes and rivers is different from productivity in deeper waters.

The measurement of changes in trophic dynamics is easily done in small units such as watersheds. However, exhaustive measurement and testing is necessary to evaluate trophic structural changes on large regional bodies of water, particularly when several other water uses and pollutants may also be affecting the trophic dynamics. A thorough investigation of food web structure, even at one location, is extremely difficult and involves large data collection efforts. The measurement of these details on a regional scale is almost impossible.

Some estimates of changes in regional productivity can be made from existing water transport models. Several such models that determine changes in primary productivity have been developed.

The cycling of minerals in aquatic ecosystems is difficult to measure except with specialized methods. On a regional scale, this process may not be an important indicator of ecological impact since materials can be recycled many times as they are transported along streams, lakes, and estuaries.

2.3 AIRBORNE POLLUTANTS

Numerous airborne pollutants result from energy development, e.g., ozone, sulfur dioxide, hydrocarbons and their reaction products, trace elements, and particulates, which may affect ecological processes. Sulfur oxides, acid rain, carbon dioxide, and radioactive residuals have been chosen for discussion here.

Sulfur Oxides

Sulfur dioxide (SO_2) released into the atmosphere can have direct effects on plants and animals near the release point and may also be converted to sulfuric acid that is carried to the earth in rainfall. The effects of SO_2 gas on ecosystem processes will be considered separately from the effects of acid rain.

The effect of a given ambient or transient level of SO_2 on growth and productivity of soybeans can be estimated, roughly within a factor of two. Yield reductions can be predicted less well for other crops, although it appears unlikely that corn will be affected at concentrations that are likely to occur. Very little is known about SO_2 effects on forests or other natural ecosystems, with the exception of short-grass prairie, which is being studied in Montana.

Although there is presently an active research effort to develop atmospheric models that predict peak and mean concentrations in the vicinity of point sources of air pollution, it is not clear that these models will be capable of the detailed predictions needed for accurate forecasts of yield reductions in the vicinity of even one SO₂ source. Even when useful models are available, scaling their predictions up to estimate yield reductions on a regional or national scale will be very difficult. We will not soon be able to predict accurately that n tons of residual SO₂ released into the atmosphere by a given energy technology will reduce soybean yields by x million bushels. However, if quantitative estimates of yield reductions could be made it would be relatively easy to calculate their economic importance.

The productivity of some crops in sulfur-deficient areas may be increased by the fertilizing effects of low levels of SO₂. The magnitude and significance of these increases can be predicted with about the same level of accuracy as that of the predictions of decreases in productivity that result from higher levels of SO₂.

Sulfur cycling would be affected by the addition of gaseous sulfur from the atmosphere in some areas. The main economic effects of this change would probably result from crop productivity increases because of sulfur fertilization. Cycling of other elements is not likely to be affected by the direct effects of SO₂, unless SO₂ levels become so high that growth and productivity are reduced sharply and nutrient leaching begins to increase significantly. No processes in aquatic ecosystems are likely to be affected by the direct effects of SO₂, although reduction in nutrient uptake by terrestrial ecosystems could result in increased leaching into aquatic systems.

Acidic Deposition

Acidic deposition is a regional phenomenon, perhaps national and multinational, that has potentially serious ecological consequences. At present, we do not possess sufficient information to define the magnitude of potential effects and their geographical distribution. We do, however, possess methods to measure those quantities and should give high priority to establishing a national study program to do so. It should be recognized that such a program will cost tens of millions of dollars and take up to a decade to complete.

At present we do not fully understand how acidic substances are formed in the atmosphere (EPRI 1978); hence it is not possible to quantify the acidic deposition associated with specific energy technologies to specify pollution control strategies that would decrease acidity by given amounts. The formation of acidic substances in the atmosphere is another area of study that should be given high priority.

Terrestrial processes with the greatest potential of being affected by acidic deposition and therefore of major concern are:

1. Element cycling - Increased inputs of sulfur, nitrogen, and hydrogen ions into ecosystems can leach cations from foliage and soil, increase weathering of

minerals, and alter rates of processes mediated by microorganisms. Sufficient data do not exist to quantify changes at this time. Methods of measuring changes in element cycling exist, but the ecological significance of quantified changes is not easy to interpret.

2. Productivity/growth - A recent international conference on the effects of acid rain (Anon. 1977) concluded that existing data regarding effects on productivity are ambiguous, and that more studies are needed. Measurement methodology is adequate for short-term effects but not for long-term effects resulting from chronic low-level exposures. If changes are quantified, then their ecological significance can be stated.

Aquatic processes with the greatest potential of being affected by acidic deposition are:

1. Element cycling - Cycling of elements can change acidity and concentration of cations in surface waters. The role of atmospheric deposition in lake acidification, in comparison to the roles of other ecosystem sources of acids, is controversial (see, e.g., Rosenquist 1978a, 1978b; Seip and Tollan, 1978). Further studies are needed to resolve this controversy and to quantify effects. Measurement methodologies exist, and ecological significance can be stated if changes are quantified.
2. Productivity/growth - Acidic deposition can decrease fish productivity. This decrease results from an increase in either acidity or the concentration of toxic elements, e.g., Al^{+++} . The buffering capacity of materials derived from the underlying geology is important in this regard. Methods to assess these changes exist, but more research is needed to determine impact limits and buffering capacity. If changes are quantified their ecological significance can be stated.

Carbon Dioxide

Combustion of fossil fuels, particularly coal, increases the concentration of CO_2 in the atmosphere. Approximately 10^5 tons of CO_2 is released per 10^{12} Btu of energy produced in coal-fueled power plants. About half of the released CO_2 remains in the atmosphere, and the remaining half is being removed by natural biogeochemical and ecological processes. Carbon dioxide released into the atmosphere cycles rapidly, and global monitoring data currently indicate a CO_2 growth rate of 0.3% per year. The current capability for describing global carbon cycles and atmospheric CO_2 concentrations is well-documented.

Three broad classes of effects result from increased atmospheric CO₂: climatic change, possible effects on productivity, and linkage to the biogeochemical carbon cycle. The main concern about global climatic change is related to the "greenhouse effect." Changes in global climate have been projected from climate models; however, regional climate projections have not been done. Expected ecological consequences of climate change include effects on biological productivity, land and ocean modifications, cryosphere changes, and impacts on social, economic, and political systems. Responses to climate change are manifest on regional and global scales. We are capable of estimating global climate change as a function of the greenhouse effect, but there is a need to validate such estimates.

The release of CO₂ during fossil fuel combustion has direct implications for the biogeochemical carbon cycle. Flow of carbon in the carbon cycle determines its atmospheric residence time and its ultimate fate in terrestrial and oceanic sinks. A major uncertainty of the carbon cycle involves mixing rates in oceans, viz, rates of deposition in deep ocean sediments. Another major uncertainty is whether the terrestrial component of the biosphere represents a source or sink for CO₂. Carbon dioxide generation in the biosphere as a result of vegetational changes and from oxidation of soil humus has not been quantified.

Knowledge of the global carbon cycle is limited. Atmospheric CO₂ concentration has been accurately measured, and trends have been analyzed well. Absorption of CO₂ by oceans is understood, but rates of transfer to ocean sediment are not known. Both empirical data and mixing models are needed to describe the carbon cycle of oceans. The contribution of carbon to the atmosphere from changes of the terrestrial component of the biosphere (deforestation, humus oxidation, optimization of photosynthesis) has not been quantified.

A rudimentary capability exists for estimating photosynthetic response to increased ambient CO₂, but functional relationships need to be developed between carbon fixation and water availability, fertility, and microclimatic variables.

There are no physical and environmental models for integrating climatic change, environmental effects, and socioeconomic consequences in preparation for energy policy evaluation. Existing methodologies may be applicable, but test cases need to be examined.

Radioactive Residuals

Radionuclides are a residual of the nuclear fuel cycle and of coal combustion. Methods of assessment are superior to those used for most ecological changes. The technology for safe and effective storage and management of radioactive wastes should be adequate, once social and political constraints are removed. The chief concern is for continued assessment of large volumes of low-level radioactive wastes buried in shallow repositories during past decades. The ecological effects of these wastes are localized.

2.4 LAND-USE CHANGES DUE TO ENERGY TECHNOLOGIES

To varying degrees, all energy technologies contribute to land-use changes and habitat modification. Extraction of fossil fuels results in retrogression of succession, short term reduction of productivity, and addition of elements to ecological cycling. Methodologies for assessing changes in these processes are well-developed. Conversion of biomass to energy products could have significant impacts on several ecological processes, including trophic dynamics and element cycling, and could cause qualitative changes in productivity. Natural resources essential to achieving maximum productivity of biomass are also essential to the productivity of agroecosystems. Development of an energy technology that will compete with agroecosystems for the same essential resources deserves careful examination. Tradeoffs can best be measured in terms of quantitative changes in productivity.

Changes in land use may increase the quantities of water entering streams as well as change the timing of water entering streams. An increase in surface runoff may cause leaching and soil erosion, which results in greater loads of suspended and dissolved materials in the surface waters. A high level of suspended solids reduces light penetration, increases temperature, reduces stream oxygen levels, increases bottom sedimentation, and can clog the gills and filter-feeding mechanisms of aquatic organisms. These physical changes reduce primary and secondary biological production, change the trophic dynamics of the system, and greatly modify species composition. An increase in dissolved materials can result in the long-term reduction in productivity of terrestrial systems as well as in species changes, since nutrients are being removed from these systems. Instream there will be short-term increases in production (if not accompanied by a high concentration of suspended solids), but, in the long range, productivity will likely be reduced. Shifts in trophodynamics are also expected.

Models are available for handling problems of erosion and sediment transport, and dissolved-substance transport and utilization. Qualitative information on the effects of suspended solids is available, but details are not well-known and are not really quantifiable in terms of ecosystem processes. The loss of topsoil and nutrients and decreases in terrestrial and aquatic productivities are socially significant.

2.5 ASSESSMENT ON A NATIONAL SCALE

Ecological science can make valuable contributions to assessments of energy technologies done on a national scale. We believe that "watersheds" at the scale of second-order streams represent the upper limit of our ability to assess, with acceptable precision, changes in ecological processes. However, extrapolation to a larger geographic scale is possible by aggregating information from a number of selected watersheds. The accuracy of the aggregation depends on whether data-gathering methods were comparable in quality and sophistication. Aggregation is dependent on the implementation of a national environmental monitoring program characterized by standardized methodologies as well as on the establishment of a central federal office for ecological inventories, monitoring, and analysis.

Some ecological processes, such as productivity, are ubiquitous enough to transcend geographic constraints, and assessments of changes in these processes can be undertaken at the national level. Objective assessments conducted at one geographic or temporal scale can be meaningfully extrapolated to a larger scale if subjectivity and loss of precision are acknowledged.

3 POPULATIONS

In attempting to outline the kinds of impacts and alterations that will be of primary concern for an ecological impact assessment, the Populations Task Group identified the following categories:

1. Change in productivity - Reduction in, for example, timber, corn, milk, or salmon traceable to certain causative factors.
2. Consequences to "special" species - Five categories of "special" species that can be used as measures of impact were defined:
 - a. Rare
 - b. Endangered
 - c. Dominant
 - d. Indicator
 - e. Keystone
3. Restoration potential - The probability that an adverse effect could be reversed with reasonable effort, time, and resources.
4. Toxic material transport and accumulation - The quantities and release rates of toxic substances that will be generated by an event or source and that will become a burden on the environment.
5. Unpleasant rearrangement of the landscape - A number of examples of this effect can be provided: destroyed forests; heavy soil erosion; destruction of interesting rock formations (e.g., the "Garden of the Gods" in Colorado); hillsides stripmined for coal.

Of the five categories listed above, the "Consequences to 'Special' Species" was addressed by the task group.

3.1 RARE SPECIES

Definitions and Basis for Concern

Populations of rare species represent an important source of ecological information, particularly with regard to species diversity and genetic diversity (i.e., the total gene pool). It is important to recognize the distinction between populations of rare species and those classified as endangered in state and federal lists. Perhaps the most obvious difference is that "typical" ecological entities such as communities, food webs, or trophic segments often have in their membership varying numbers of relatively rare species that may or may not be classified as endangered. Frequently, rare species appear as low density populations, relict populations, populations at the extreme of their range and/or populations occupying isolated habitats. In some cases, the isolation or uniqueness of the habitat makes the habitat itself rare. Low density coupled with isolation, range extremity, or relict status often make populations of rare species more susceptible to damage from perturbation.

Data Availability

Data on rare species are available in published and unpublished (e.g., nature societies, garden clubs, government reports, computerized data bases) forms. However, in most instances data sources are not centralized or assembled as summaries of rare species or isolated or unique ecosystems. Data thus need to be accessed and scrutinized to produce an index of rare-species populations. One major problem in assembling a list of rare species is how to deal with obscure data, e.g., species lists with a component such as "unidentified species." Another problem is that of developing useful methods to identify and define what makes a species rare.

3.2 ENDANGERED SPECIES

Definitions and Basis for Concern

"Endangered species" are defined as those listed or proposed by the federal Office of Endangered Species or by equivalent state offices as being endangered or threatened. Thus, the class of endangered species is a legal entity and from this follows one basis for concern: the species are protected by a detailed and carefully defined set of regulations. The biological, moral, and esthetic reasons for preserving endangered species may thus be of secondary concern from a practical point of view. The value of endangered species is not a matter of debate; it has been established by law. In the extra-legal sense, the concern for endangered species is based on the fact that they are rare and thus more susceptible to environmental perturbations.

The problem of endangered species is addressed by determining where the species occur, the reasons for their endangerment, the factors critical to their immediate survival and recovery, and finally, to what types of impacts they might be particularly susceptible.

Data Availability

The most comprehensive collection of data on the range and biology of endangered species is in the files of the Office of Endangered Species in Washington. Unfortunately, these data are chaotic, unstandardized, and not readily accessible. Brookhaven National Laboratory has been organizing taxonomic and range information at the county level for all species in their files. Historic and present ranges are included, as well as counties containing critical habitats. The Brookhaven data include no biological information such as productivity, population size, minimum habitat requirements, sensitivities to residuals, and management potential. To obtain such information one must rely primarily on printed literature, although the Sensitive Wildlife Information System (SWIS) contains detailed data, but, unfortunately, on only a few species. Various states (e.g., Mississippi) have excellent information, often computerized, on the distribution and ecology of their endangered species.

The confidence one may have in the endangered species data varies immensely. The eastern cougar formerly ranged over much of the eastern U.S. but now cannot be assigned to any particular county with any certainty.

By contrast, the world population of certain fish species can be located to single small springs in the West.

The method for an endangered species assessment, already used in several studies, is basically one of matching energy-facility sites with range information, but more precise methods of evaluation have not yet been developed.

Data Requirements

Because the concept of an endangered species is well-defined and politically important, data requirements for geographic assessments on a large scale have been met. Site-specific assessments require field work and are probably being done in environmental impact statement studies.

The Problem of Geographic Scale

Figure 3.1 illustrates the reliability of endangered species data for areas of different sizes. For the nation as a whole, the data are almost completely reliable in that all species listed are known to occur in the country. The level of confidence then drops somewhat as one approaches the county level, at which the distributions of many plant species are not known. Thus, the value of the endangered species data for ecological assessments also varies with the geographic scale of the assessment. Such data are probably most useful at a level somewhat above the county; for example, for areas about the size of the small river basins identified by the Water Resources Council, as well as for a larger regional level (multi-state), where the existence of endangered species is still evident. For example, the Appalachian Region is distinctly richer in endangered species than the cool areas of the Northern Great Plains.

3.3 DOMINANT SPECIES

Definitions and Basis for Concern

Dominant species are those that contain numerous organisms, account for a major proportion of the biomass, or are major pathways through which energy and/or money flow. These species are of major concern for several reasons: first, populations with high biomass or numerous individuals may be crucial in determining pathways of money, energy, nutrients, and water through ecosystems; second, these populations may be indicators of ecosystem attributes, such as quality or condition of the environment; finally, dominant organisms may determine the resiliency of systems to perturbations and thus the restoration rate and restoration potential of ecosystems.

By their nature, dominant populations are major regulators of ecosystems, and changes that affect these populations may have major implications for system behavior. Dominant species are frequently both conspicuous and of significant economic importance. For example, domestic livestock or

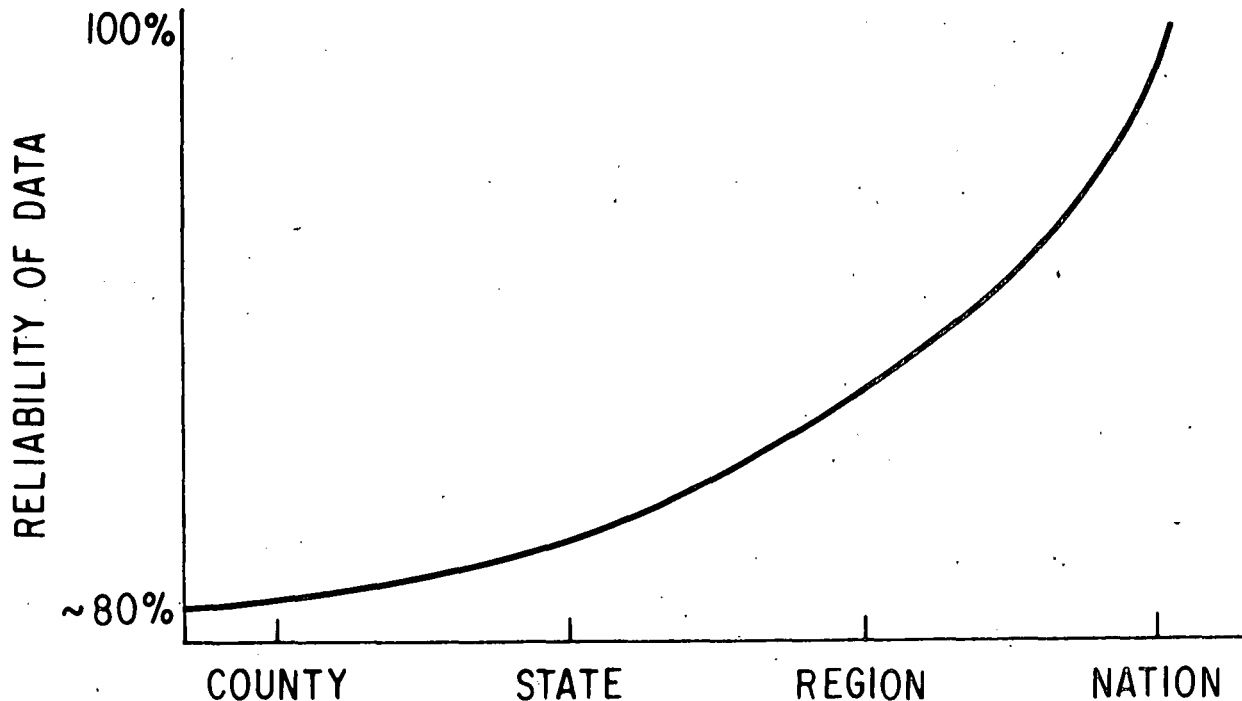


Fig. 3.1. Reliability of Endangered Species Data
as a Function of Spatial Scale

wildlife may be dominant organisms that play a major role in the livelihood of human populations in their immediate vicinity and elsewhere.

Data Availability

There are adequate data sources on most dominant species, and methods exist for obtaining such data, which are largely presence or absence tallies and numbers. Distributional data are related to known habitat types and environmental conditions. The information is more comprehensive for plants than for animals although animal data are adequate in most cases. However, the estimates of animal populations over large areas are dependent on the identification of habitats and the relationship of animal populations to specific, identifiable habitats.

Information on the distribution of dominant plant or animal species can be found in numerous accessible sources such as computerized herbarium or museum records, published distribution maps, Forest Service computer files, and published reports. Productivity or growth data for plants are available from the Agriculture Report Service, timber inventories, and production profiles from numerous states and from individual studies. These types of data for animals are less plentiful but exist for various counties and states

in the files of game and fish departments or universities and in specific studies on the growth and production of individual communities or ecosystems. Data on fish distribution are available from game and fish departments, cooperative wildlife units and individual studies. Information on aquatic plants is less plentiful, but exists in individual studies. Universities, regional laboratories and research institutes are also excellent sources of all this information.

Although data sets for dominant species are available, much of the animal data and the vegetational units in which plant data are organized have not been correlated. This has been done in some cases, but an organized data base exists for only some vegetational units.

Data Confidence

Data confidence is generally high, although there are some caveats. The quality of purely distributional data based on herbarium and museum data is subject to the habits of collectors. Data on productivity is limited by the degree of methodological comparability and by differences in calculation techniques. For some groups, e.g., insects, existing sampling methods are inadequate for characterizing, within narrow confidence limits, any attributes more elaborate than presence or absence.

Measurements and confidence levels for data on domestic livestock and crops are adequate for virtually all spatial scales but less so for time scales. Larger time scales are less adequate because of such variables as economics, weather conditions, and technological developments.

Spatial Scale

As the spatial scale increases, data reliability may decrease. In cases where the area is small enough for a census of the organisms, data confidence may be high, e.g., $\pm 10\%$ at the 80%-confidence level. However, when the spatial scale is larger than the feasible census area, two confounding factors enter. First, the area is heterogeneous, and estimates depend on the correct segregation of similar habitat types. Second, estimates from more dissimilar locations must be used as the size of the area increases.

Most data sets are easily aggregated to the state level because crop and livestock data are reported at this level and because other species are either reported at the state level or by vegetational types that are mapped at the state level. State data can be aggregated at higher spatial scales although as noted above, data confidence decreases as the geographic scale increases. However, for most policy issues, the information is adequate.

Time Scale

Data confidence diminishes through time. In the year of a census and in years in which controlling factors are near normal, confidence is high. However, as time passes and as controlling factors fluctuate, confidence decreases. These time scales vary tremendously with the organism in question.

For unmanaged communities, dominant plants are predictable for 30 years. Animal data are not predictable for such periods, and yearly estimates are required. In some cases, data are sufficiently detailed that estimates can be statistically grouped around a mean value and a confidence level can be given. In managed systems, many crops are well measured, but as economics, weather, disease, technology and sociology change, the dominants may change in species and magnitude.

Suggested Indicators

Dominant species that can be useful for scenario development and/or an energy technology assessment can be identified, depending on the spatial scale for which information is sought. For example, rhododendron in the heath balds is indicative of this specialized community, just as bog laurel and leather-leaf are useful indicators of bogs. The loss or perturbation of these dominant species would result in substantial changes in the community or ecosystem. Indicators of the central grasslands are the little and big bluestem, sideoats grama, leadplant, and globe mallow. Similar lists could be constructed for aquatic populations, crop plants, livestock, and wildlife species. The response to exposure to various residuals and resultant change in land-use patterns is known for most but not for all of these populations.

Data on the response of indicator species to various impacts are not currently organized but could be relatively easily assembled into a data book, which would list the following categories:

- Species
- Distribution
- Amount of biomass
- Susceptibilities to residuals
- Role in ecosystem
- Responses to land-use patterns
- Other specialized information

3.4 INDICATOR SPECIES

Definitions and Basis for Concern

Indicator species can be used to flag significant changes in a system of importance. For instance, invasive species can indicate the action of destructive or disruptive forces. A decline in populations of sensitive indicator species can indicate changes in external influences such as air quality. Conversely, maintenance of such indicator populations may indicate "healthy" communities. For example, the presence of SO₂-intolerant lichens in an eastern hardwood forest indicates good air quality and consequently relatively pristine conditions. Indicator species may be: (a) present -- which suggests the absence of noxious, toxic materials in the environment; or (b) absent -- which suggests, but only suggests, the presence of toxic materials beyond a threshold level. "Absence" of an indicator could result from a number of causes, e.g., white pines may have been cut down as timber or wiped out by disease rather than diminished in number or wiped out by poor air quality.

In general, the number of species is a measure of the status of the community. For example, a benthic sample containing only chironomid larvae and/or tubificid worms indicates a polluted stream, lake, or estuary. Number of species is useful only in comparison with similar plant and animal communities. In the example above, a benthic sample taken from a clean body of water of the same region normally would have 10-30 species in a single sample. However, a low number of species could result from other causes. For example, the number of species may be small in a sample taken from a steep-sloping section of a stream because the rocky substrate or excessive current may reduce faunal diversity there in comparison to other parts of the stream. In another example, the composition of a forest may be determined by poor soils or low moisture rather than by perturbation.

Data Availability

Species that are indicators of system health and vigor are the most useful in non-site-specific assessments of impacts, but data on such species are less accessible and indicator species are still being identified. For example, the SO₂-intolerant lichens are valuable as indicators of good air quality, but there is little information about the distribution of these species in the U.S.

The published literature may contain accounts of cases in which species are replacing one another because of changes induced by a specific facility such as a power plant or hydroelectric dam. For example, siltation of streams and rivers would favor largemouth bass over smallmouth bass; the latter requires sandy or gravelly stream bottoms for feeding, egg laying, or during some other part of the life cycle. Thus, the replacement of smallmouth by large-mouth bass may indicate a change in the health and vigor of the aquatic community. A few examples of indicator species are given below.

1. common loon -- present only in relatively undeveloped lacustrine areas.
2. heron rookeries -- present in relatively undisturbed or remote areas with lakes and streams.
3. scarlet tanager, certain warblers, others -- such birds only nest deep in undisturbed forest.
4. raven -- indicator of low human population density; undisturbed areas.
5. species of fish -- many cyprinids and others require exceptionally good water quality. Mosquitofish (Gambusia) flourish in the absence of competitors that have been eliminated because of water pollution, especially by organic wastes.
6. orchids, gentians, others -- intolerant of physical perturbation or changes in air quality.
7. moose -- indicate the presence of second growth.

Indicator species can sometimes be identified by remote sensing. For example, color aerial photography can reveal chlorotic white pines (Pinus strobus). Similar information can be obtained either from formal literature or from monitoring programs.

3.5 KEYSTONE SPECIES

Definition and Basis for Concern

Keystone species are those that can have more important effects on their physical or biological surroundings than their numbers suggest. The consequences of the presence or absence of keystone species are generally amplified because of their function as regulators of the total ecosystem. Keystone species fill at least three important ecosystemic roles:

1. Stabilization of the physical environment,
2. Stabilization of the biological community, or
3. Maintenance of the productive cycle of the parent community.

Keystone species are important because of their functional role in the environment and thus provide the basis for establishing ecological principles. These principles are then generalized to broader contexts, where they often serve to identify potentially important mechanisms in more complex ecological settings. Thus, keystone species are inextricably interwoven into ecological systems, as illustrated in the following examples of keystone species functions.

1. Stabilization of the physical environment:
 - Processing of important chemicals -- blue-green algae metabolize ammonia.
 - Stabilization of soils or substrates, or retention of water -- grasses prevent sand-dune erosion.
 - Creation of habitats for other species -- woodpeckers create holes for cavity-nesting birds.
 - Maintenance or preservation of the physical environment during periods of high stress -- wind-breaking trees or shrubs reduce wind erosion during droughts.
2. Stabilization of the biological community:
 - Protection of the community from invasion by foreign species -- beech trees prevent encroachment of sub-climax trees.
 - Prevention of population explosions -- wolves hold down caribou population levels; large predators preserve a natural balance with deer populations; and lady beetles control citrus scale insect pests.

- Maintaining diversity of related species -- for example, arctic foxes switch from hares to lemmings when hares become scarce; birds switch to the most abundant butterfly species.
 - Supporting a symbiotic partner -- for example, bees pollinate fruit trees.
3. Maintaining the productive cycle of a biological community:
- Continuation of primary production in the food chain -- algae in aqueous systems.
 - Reduction of detritus to usable nutrients -- termites and other species in forest systems.
 - Capturing portions of the resource spectrum not accessible to other community members -- lichens subsisting on rocks or birds capable of eating large seeds.

Data Bases and Validity of Assessments

Many of the most well-understood ecological relationships involve keystone species, and these species could be entered into a generic data base in the near term. For more complex, or less well-known ecosystems, information should be solicited from those with the most experience, since the importance of a keystone species lies in its systemic role, and only those experienced with the ecosystem can assist in identifying such species.

Somewhat greater relevance might be obtained if the concept of keystone species were generalized to include a cluster of species performing the same essential function in an ecosystem. It may be that energy-system impacts act on the entire class as certainly as on individual species; hence verification of important impacts would be much simpler.

3.6 THE SPATIAL SCALE OF POPULATION ANALYSIS

The usefulness of the five types of species in assessments of different geographical scales is illustrated in Fig. 3.2. Although other types of spatial classification systems are available (e.g., soil conservation districts, water districts, etc.), the political divisions of county, multi-county, state, region, and nation were chosen as spatial units. As the graph shows, dominant species are useful at all levels of analysis. Indicator species are important sources of ecological information at the county, multi-county, and state levels, but their usefulness drops sharply as the analysis moves from the state to the regional and national levels. Rare and endangered species are most useful for regions between county and multicounty size, whereas keystone species are most useful at the county level.

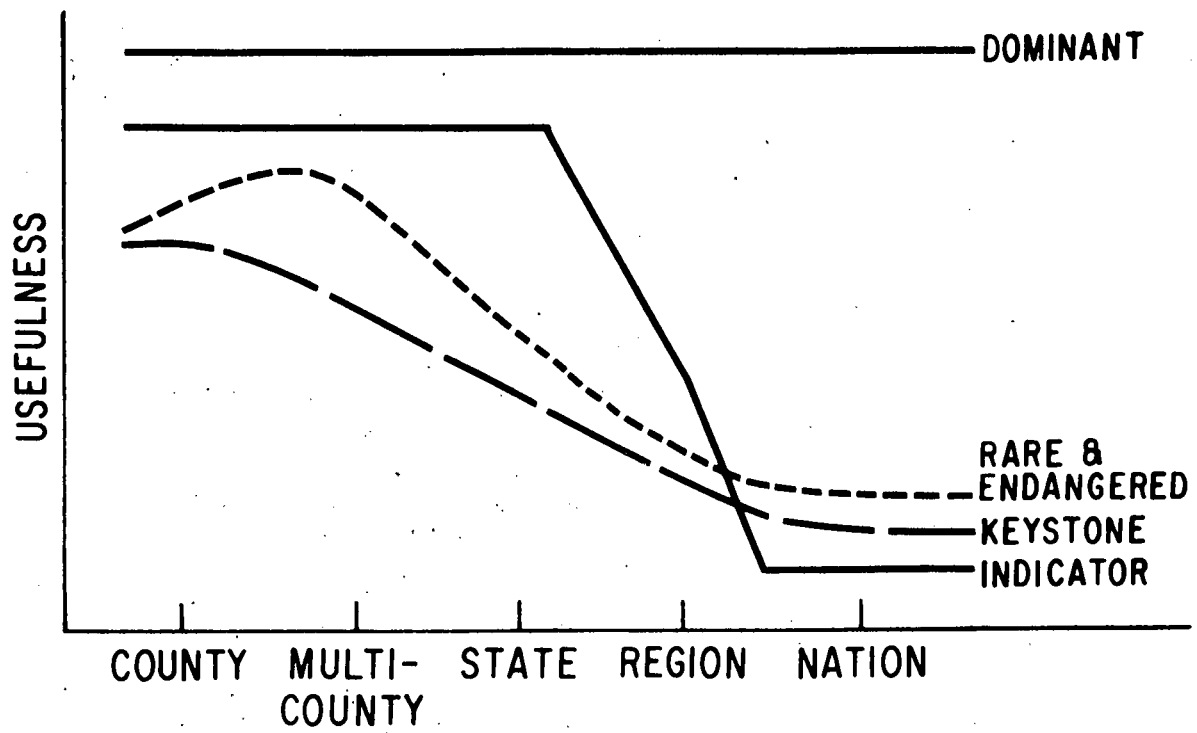


Fig. 3.2. Value of Population Impact Analysis for Ecological Assessments at Different Spatial Scales

4 ECOSYSTEMS

Most environmental assessments since the passage of the National Environmental Policy Act (NEPA) of 1969 have focused primarily on discrete biological populations within terrestrial, freshwater, or marine systems. But ecosystems exist as integrated biophysical complexes. They occupy space, exchange materials, and can be considered at different levels of generalization from the biosphere down to an individual unit of relatively small size, such as a pond or a forest stand. We fully recognize that jargon has been the age-old curse of ecology, and that the term "ecosystem" means different things to different people. Watersheds, formations, biomes, landscape units, ecoregions, and several other terms have been coined through the years. Most of these terms, however, are used in reference to a spatial complex of biotic and abiotic variables that essentially form a functional unit. We do not intend to either resolve or perpetuate this confusion. Instead, we emphasize that a variety of geographical scales and landscape units can be and have been delimited on the basis of various criteria. This approach is much more practical for energy-related assessment than the intricacies of logic that result in a spate of terms defining the same idea.

Consequently, we are addressing those system phenomena that may emerge at several geographical levels, in different taxonomic orders, and in different magnitudes in obviously different environmental regions. We are searching for those commonalities that transcend terrestrial and aquatic subdivisions and that operate in similar fashion regardless of latitude, longitude, or elevation. We are examining the complex of processes, populations, and associated diverging variables that serve to identify mappable units, whatever the scale may be. Thus, for our purposes, we recognize a hierarchy of systems that we have chosen to call "ecosystem," "watershed," "region," "ecoregion," and "continent."

Regional variations in climate, vegetation, and soils are important in the development of ecosystems. For this reason it is important to recognize regions in analyzing the effect of energy technologies. And, since different energy technologies may be restricted to different regions of the United States, an analysis of ecosystem-energy technology conflicts can be regionalized. For example, oil-shale development and the deployment of geothermal wells will be restricted to relatively small areas of the western U.S., and a conflict analysis could concentrate on the sensitivities of ecosystems in those regions.

Different technologies will generate different impact potentials, depending on engineering, waste effluents, resource consumption, and other process-related mechanisms. For example, thermal aquatic plumes will create kinds and magnitudes of ecological impacts that differ from those generated by the mix of organic compounds emanating from coal liquefaction and gasification processes. Finally, impacts will differ depending on ecosystem type, particularly those of major divisions such as terrestrial and aquatic. A three-dimensional conflict matrix could be developed, with regions, ecosystems, and technologies as the three axes. Regions would correspond to the "ecoregions" proposed by Bailey (1978). Ecosystems would cover the range from terrestrial to aquatic systems.

When the conflict matrix is developed, a number of steps are recommended for its efficient use. First, those regions of the country where a specific technology is applicable must be identified. Second, the technological processes that will have potentially important impact or will impinge on regional ecosystems must be identified. Third, those ecosystem types most likely to be affected must be delimited within each region. Fourth, those subprocesses or residuals of the energy technology that will affect specific ecosystem properties or parameters must be evaluated, quantified, and assessed. For example, changes in species composition that affect both structure and function must be placed in perspective and used in national assessment of energy technology scenarios.

4.1 SPATIAL CLASSIFICATION OF ECOSYSTEMS

Spatial classification of ecosystems is required in order to: (1) predict the impacts of energy-related activities on ecosystems at the local and regional scale; (2) extrapolate research results and management experiences from one geographic area to another; and (3) partition the natural variation in the environment into more homogeneous units to increase sampling efficiency.

There is currently no approach to ecosystem classification that is generally accepted or used within or among agencies concerned with energy development. Various approaches have been developed; however, there are no quantitative data or methods available to determine the effectiveness of alternative schemes of classifying ecosystems. Lack of a common language is part of the difficulty in selecting a scheme since terms like ecosystem, classification, inventory, analysis, etc., are interpreted differently. Some concerns that should be reflected in a common definition of terms and in the process of ecosystem classification include:

Inventory	What are the resources of the ecosystem? How much is available within as well as among ecosystems? Where in the ecosystem are these resources located?
Interpretation	What is the demand for the resources inventoried? How does demand relate to supply? (What is the approximate "value" of the resources?)
Evaluation	What are the responses of the inventoried resources and what is their "value" to alternative land uses and/or management practices?

Regardless of the approach used to classify ecosystems two basic questions must be addressed: (1) What criteria will be used to identify an ecosystem? and (2) How do we identify different levels of generalization in a hierarchy of spatial units? The ideal classification should accommodate terrestrial and aquatic (fresh water and marine) systems and the terrestrial-aquatic ecotone. It should also integrate the concept of multiple factors in a specified space and be flexible enough to accommodate user need for general classification in regional, national, or state planning, as well as providing a framework to meet user needs for specific classification.

Two examples of what the ideal ecosystem classification provides that an analysis of populations or processes will not provide are:

1. Resource interactions within and among ecosystems.
2. Processes that emerge from these interactions -- death rate, soil erosion, trophic dynamics, and animal habitats that include aquatic and terrestrial environments.

4.2 REGULATION OF STRUCTURE, COMPOSITION, AND FUNCTION OF ECOSYSTEMS

Diversity, the number of trophic levels, and the productivity of ecosystems are influenced by the regulation of the systems' structure, composition, and function. Since these are central ecosystem properties, it is important to examine the effects of energy development and residuals on these attributes.

Diversity should be examined in terms of the full range of biotic taxa, if possible, since ecosystems may have a greater total species diversity than is reflected in the diversity of one taxon or life form. For example, ecosystems on xeric sites have a lower diversity of woody species but a greater total botanical diversity than systems on mesic sites. The relation of diversity to regional perturbation regimes and rates is also important. For example, Heinzelman (1973) indicated that a natural fire rotation cycle resulted in a maximization of diversity in the Boundary Waters Canoe area in Minnesota.

Productivity is influenced by ecosystem structure and distribution of biomass. For example, subjecting a Portage, Wisconsin marsh to winter thermal heat loadings led to replacement of perennials by annuals, which in turn led to lower rhizome production and subsequently higher spring losses of substrate and nutrients.

Residuals of energy technologies can influence naturally-occurring "controls" of ecosystem structure and composition. Extraction and reclamation activities may introduce a new habitat and exotic species (at least temporarily), which may persist as an anthropogenic "innovation" for up to a century. Gaseous emissions, oxidants, and acid fallout, either separately or in combination, have eliminated from ecosystems some species (often nitrogen-fixing species) that often are not replaced by species of similar function. In general, the elimination of species results in increased leakage of elemental nutrients from the system. Nutrient stresses that weaken trees or crops to the point of enhancing the likelihood of insect infestations are another common form of weakened "regulation."

Much of the background data and models for non-site-specific analyses are available for a limited number of terrestrial and aquatic ecosystems. Types of residual will have to be examined individually so that production of secondary products (e.g. mobilization of acid-soluble toxic elements by acid fallout) is considered.

4.3 PATTERN OF NORMAL STRESS AND ALTERATION BY MAN

Ecosystems and their component species are adapted to a given range of climatic and edaphic conditions. Their existence requires that the system survive the normal incidence and degree of perturbation. In fact, the system may depend on disturbances to maintain species diversity.

In general, normal stresses serve to provide nutrients, to reduce populations by eliminating diseased or injured individuals, or to permit reproduction. Increase in either the frequency or the magnitude of the disturbance or elimination of the disturbance may significantly alter the ecosystem. For example, marshes and wet prairies exist under a fluctuating water regime. The dry portion of the annual cycle permits reproduction to take place and stimulates changes in both species composition and system process. The northern dry mesic forest of the midwest (pine forest) is composed of shade-intolerant species. In time, the forest is invaded by shade-tolerant species and pine reproduction is hampered. Infrequent (100 to 300 years) fires serve to remove the broadleaf species and to initiate successional processes leading again to dominance at the conifer forest sere. Fire control has prevented these natural sequences of catastrophe and succession over large areas. Many similar examples can be cited, from the establishment of vegetation on shorelines, to effects of wind in old-growth forests, and to flushing of rivers and estuaries, which replenishes nutrient supplies or removes toxic substances.

Perturbations and system adjustments to substantial alterations can be examined by well-established phytosociological and physiological methods.

4.4 REGULATION OF BIOCHEMICAL CYCLING

Relevance and Utility for Analysis at the Ecosystem Level

Individual processes and the activities within one niche of an ecosystem are not independent of the other elements within the ecosystem but rather are controlled and limited by the rate of flow (cycling) of material and energy throughout the system. This approach to impact assessment begins where single process analysis or single population analysis stops by addressing the following questions: Is a direct impact promulgated through the trophic structure of an ecosystem to other elements? Is the impact magnified during the transmission process or is it dampened? Which other components of the system are subject to impact as a result of a direct impact on one component?

It is possible that the same physical insult will generate vastly different system responses in two seemingly similar systems. The underlying difference is often found not in the basic system structure but in the rate of transfer of the initial insult into other system elements and in their ability to withstand that flux or change. This may be called the system buffering capacity, the recycling or turnover rate, or even the system's elasticity, among others. Two major approaches to the measurement of this phenomenon are introduced in the following paragraphs, and general suggestions are made for the appropriateness of this technique for the impact assessment of energy development.

Single Factor Indices

In general, two types of indices have been identified. The first is an index that identifies the limiting factor(s) to the energy or material flows within an ecosystem. In simple aquatic systems this factor is often nutrient availability (the system is nutrient-limited). However, a variety of other factors (e.g., dissolved oxygen content, light availability, habitat availability) can act to limit and control overall ecosystem activity. It is generally true that direct insults to factors or transfer rates other than the limiting ones within the system will be dampened as they ripple through the system, whereas those to the limiting processes are not dampened. Thus, in a lake ecosystem that is nutrient-limited, an external activity that reduces dissolved oxygen content would not be expected to produce as significant an impact on the system as one that directly affects nitrogen and phosphorus availability.

The second type of index is one that describes the overall cycling efficiency or flow of materials throughout a system. Indices of specific mineral/chemical constituents have been developed and applied to a number of ecosystems. As such, they can now be used as indicators of normality (to determine whether a system is actually similar to other systems of similar structure) and as indicators of temporal change within a specific system. Carbon cycling indices have been used to characterize several lacustrine ecosystems.

The remineralization rate for an ecosystem describes the frequency with which nutrient minerals are recycled within the system. Such indices provide valuable insights both into the direct impacts of marginal changes in the external supply rate of these minerals and into the magnitude and rate of transmission of the resulting ecosystem-wide impact or response. Thus, a cycling period of a day would indicate both the time scale over which the system response might be expected and the relative importance of changes in the external loading rate (lb/day) by revealing the total system use of nutrients over that same time period.

Single factor indices are good quick references to the character of an ecosystem but are limited in their applicability to relatively complex ecosystems. Large diverse systems tend not to display the static equilibrium inferred by a single index, but rather to display dynamic responses to spatially and temporally varying controlling factors. In such cases the following modelling techniques are of greater utility.

Static Models

Input/output (I/O) models have been developed to describe the interactions of a human economy but have also been applied to environmental questions and to natural ecosystems. These models are capable of predicting the system response to small changes in either external or internal factors and are generally used to give results in annual increments. Both the system structure and the rate of material transfer within the system are statically fixed, and thus the impact of a major change in the system characteristics cannot be accurately assessed. Within these severe limitations, I/O models are much less data-intensive than are dynamic models. The development of an I/O model

will indicate the pathways along which an impact will be transmitted through an ecosystem and may indicate the degree to which an impact will be buffered by the system. Thus an I/O analysis in general provides more qualitative than quantitative information for an impact assessment but may provide good quantitative information for systems with long cycling periods (annual) undergoing relatively small impacts.

Dynamic Models

Dynamic ecosystem models are designed to account for the natural fluctuations and cycles occurring within a system and for the varying relationships and transfer rates between individual trophic compartments. They are designed to be predictive and can be used to quickly assess the relative impacts of a wide range of human activities or policy options on the modelled system. They are well suited for identifying the most sensitive components of a system and the impact of natural versus man-induced changes on a system. However, ecosystem models are data-intensive, time-consuming to construct, and expensive to operate.

Because of their rapid temporal variation and short cycling periods, aquatic ecosystems have been the target of a greater modelling effort than have terrestrial systems. Although this discussion will therefore concentrate on aquatic models, the stated principles will also apply to terrestrial systems.

There are a number of tested aquatic ecosystem models that use a variety of numerical schemes and computer stepping and programming techniques, include a variety of basic assumptions, and organize the ecosystem into a variety of trophic components. These models include those designed for riverine systems, simple or complex lacustrine impoundment systems, estuarine systems, and marine systems. Although most aquatic models are designed for computer application, basic models that are designed specifically for hand calculation are available. Further, some models emphasize the geochemical elements of water quality (e.g., SWMM, QUAL I or QUAL II), whereas others emphasize the biological elements and calculate the geochemical components only as required as inputs to the biological compartments. The applicability of any one model depends on the system being studied and the insults being assessed.

All of these models, however, operate on two key principles -- that the system must conserve mass and energy, and that the production of any one component is controlled by the production of one or more other components and by known or hypothesized transfer or reaction rates. For example, reaction rates are generally expressed as half saturation constants for lower trophic levels, whereas for upper trophic levels density-dependent terms are used to express controlling reaction rates.

A similar general structure exists in most models. Typically the model will depend on a separate hydrodynamic model or external data file that provides information on water movement, several water quality parameters (e.g., dissolved oxygen, nitrogen, phosphorus, turbidity, pH, and temperature), primary producer (algal) components, benthic algae, detritus, herbi-

vores, and carnivores. The number of separate compartments represented within each of these general biological trophic levels varies widely. The analysis focuses on the rates of mass transfer from one or more components to one or more other components within the ecosystem or, more specifically, on the changes in these rates of transfer as a result of some external change. This is also true for models tracing energy flows rather than mass flows. Typically, hourly time steps are used for most models; however, longer time steps can be used on some models that use large spatial and trophic aggregation schemes.

The limitations of ecosystem models include:

1. The assumption that an ecosystem will maintain the same basic structure and trophic relations over time. Thus, extreme impacts that significantly alter ecosystem structure cannot be accurately represented.
2. Models are data intensive and depend on the availability of data on individual population characteristics and on the feeding habits, preferences, and options for each trophic compartment. Good data now exist for many U.S. bodies of water. However, a corresponding terrestrial data base to support ecosystem modelling efforts does not appear to have been established.
3. An ecosystem model does not know anything that the modeller does not know. Thus, the analyst must be capable of estimating or calculating the nature of all integral interactions in order to apply a model to a specific system.
4. Model and ecosystem spatial boundaries are often difficult to define. This is a major problem for many riverine and marine aquatic models and for many terrestrial systems.

Application for Energy Impact Assessment

Dynamic ecosystem models are applicable to a number of ecological assessments. They are appropriate for the study of large, relatively complex, or very significant ecosystems (prototypical or characteristic systems used to represent a large number of separate ecosystems). The model, once constructed, will support detailed analysis of a number of separate impact scenarios in a short time. The technique is particularly adapted to: the study of the impact of heated effluents from power plants on bodies of water; the application of waste heat into an ecosystem; the analysis of acid fallout impacts on pH and cycling rates; the impacts of external cycling alterations (e.g., alteration in seasonal water flow or temperature regimes); the impact of increased turbidity due to onshore land alterations; impacts of habitat reduction; the selective cropping of one or more trophic levels through the introduction of biocides, from long-term temperature alterations, or from direct mortality (e.g., impingement or entrainment); or the impacts of various combinations of these individual environmental insults.

Application to Near-Term Assessments

Summary cycling indices describing the flows of elements in aquatic systems have been shown to be very sensitive to differences in ecosystem structure (Richey et al. 1978), and to the responses of ecosystems to changing environments (Watson and Loucks 1979). These practical developments, in conjunction with the rich data base and more sophisticated models now becoming available for lakes and streams, indicate that the information is available for assessing the consequences of energy technologies on aquatic systems. Although the same principles are known to apply to terrestrial ecosystems, the summary methods and much of the data base for application to diverse terrestrial systems are not available.

Methodology/Data Needs

As already indicated, the effects of stresses on terrestrial ecosystems are known to produce a "leakage" of nutrient elements into the groundwater greater than that occurring in an unstressed system. Studies documenting this response are consistent enough to conclude that groundwater chemistry could be affected in many areas, but these studies are so scattered that no summary indices have been developed, and there is little possibility of generalizing from one ecosystem to another. Thus, there is a major need to expand basic research on geochemical responses to energy residuals, to develop more complete models of soil uptake, weathering, and leaching processes, and to validate and synthesize the results of the models.

Spatial and Time Relationships

There seem to be no major or unique analytical problems in expanding the spatial scale of geochemical responses of terrestrial and aquatic ecosystems. However, the issues explored under the input/output relations between ecosystems do need to be considered.

Time-scale problems are serious, however. Interventions in the geochemical cycle may be almost undetectable within a single year, or even five years. Such interventions can be cumulative, however, and may be serious over a period of 50 to 200 years -- the usual life span of forests. Reversibility over these long time spans also presents serious problems. Although the chemical interventions in the surface soil could be reversed in a decade, the changes in groundwater chemistry already introduced at that time may not be reversible.

4.5 ECOSYSTEM INTERACTION

Ecosystem interactions can primarily be subdivided into two divisions: (1) the flow of materials and (2) the movement of species. The flow of materials includes hydrological flow and the flow of inorganic and organic constituents carried in the water or in migrating organisms. Destruction or perturbation of any one ecosystem can affect other adjacent ecosystems.

The movement of species between the ecosystems results from different requirements of individual species for feeding, breeding, and shelter sites.

To quantify or prejudge the interactions of ecosystems requires knowledge of the hydrologic relationships between the systems and a generalized list of species inhabiting the different systems and their habitat (life history) requirements.

4.6 ECOSYSTEM RESILIENCY AND HEALTH

A number of questions must be considered in the attempt to assess the impact of an energy activity (stress) on an ecosystem. How much stress can the system take before it is altered - slightly or grossly? If the stress is applied slowly does the system accommodate? Does a threshold exist below which no effect is discernible? What is the relation between stress and ecosystem response, i.e., is the response proportional to the stress? When is the system most sensitive - spring, fall, etc? How long do sensitive or resistant stages last? If the stress is reduced (or stopped) is the system sufficiently elastic to "spring back" - quickly, slowly, partially, fully, or overshooting?

Ecologists must be able to assess (perhaps continuously) the state of health of an ecosystem. Over the centuries, medical doctors, backed by an array of researchers, dollars, and mistakes, have developed reasonably reliable techniques to measure human health. Using indicators such as temperature, pulse rate, blood pressure, some 25 blood parameters, x-ray, and urine analysis, one can obtain a general picture of a person's health. Ecologists need to develop comparable procedures to determine the health of an ecosystem, perhaps in terms of their energy flow, materials cycling, species diversity, community structure, stability, and productivity. Until ecologists can reliably determine ecosystem health it would seem prudent to preserve what are believed to be healthy examples of all major ecosystems so that they can be used for reference or for calibration.

4.7 PATCH-MOSAIC PROPERTIES: COLONIZATION

Patch mosaic is a term that describes the non-homogeneous distribution of organisms and their habitats in the environment. The properties of patch mosaics and the associated extinction-colonization processes are ecological concerns that have far-reaching consequences. The manifestations of these properties at the local scale are the pattern of patches, the size and species composition of patches, their location in space and along environmental gradients, and the stability of patch configurations. Patch mosaics are perpetuated by environmental heterogeneity and by the spatio-temporal attributes of perturbations. These perturbations might be envisioned as sequences of transient effects that are repetitive and that shift the location of patches having particular ecological attributes (Loucks 1970, Sprugel 1976). The regional ecosystem is maintained while its components come and go, and its diversity is dependent on continued perturbation. Excessive or insufficient perturbation may lead to regional extinction (Loucks 1970), which in turn can affect ecosystem productivity (Shugart and West 1977). The

regional coexistence of species is based on colonization potential, inter-specific competition, and species extinction rates in patches. Perturbation is a concomitant of ecosystem function and stability. Man does not introduce disturbance into a hitherto undisturbed ecosystem, but the spatio-temporal aspects and the agencies of perturbation are shifted. There is "perturbation swapping." The issue for analysis is the relation between perturbation swapping and altered patch mosaic properties.

It is important to remember that current patch mosaics are the product of historic land-use changes that themselves are expressions of past and continuing applications of energy-related technology, e.g., agriculture. For example, south central Wisconsin was almost entirely a mosaic of forest patches in various stages of forest succession prior to settlement. By 1870, 70% of those patches had been replaced by agriculture and the trend continues today, so that less than 5% of the original forest area remains (Curtis 1956). But this is not characteristic of all regions. Central Massachusetts was 90% deforested by 1850, but widespread farm abandonment soon after led to rapid natural reforestation and a landscape that was 90% forest by 1900. Remnant patches of natural vegetation are rapidly--and selectively--disappearing near cities, because they are frequently preferred sites for residential development or less valued for alternative uses. Each region has a characteristic mosaic of patches of natural (or semi-natural) vegetation, man-sustained vegetation (e.g., corn or pasture), and nonvegetated surfaces.

Principles for Assessing Impacts

The basis for considering the relevance of energy development on patch mosaics, either in natural or man-dominated landscapes, is that the ecology of each patch is affected by its own attributes (species composition, location, etc.) and by its interaction with other patches. Perturbation of a specific patch stimulates colonization by new species, many of which may be migrating from other patches. Disruption of this flow of species between natural patches eventually (and inevitably) affects their internal dynamics.

Although we do not know the precise thresholds beyond which critical ecosystem properties change, a number of principles can be specified for assessing the direction of the impacts of energy-related programs. These principles include:

1. Creation of patches - The first step in landscape development is preemption of portions of the patch mosaic for uses that change their participation in the patch dynamics. Replacement of natural vegetation by crops is an example. In landscapes that remain valuable for agricultural or urban uses, a limited number of patches of natural vegetation remain. This shifts attention and concern from the regional scale patch mosaic to the ecology of individual patches. Particular patch attributes then become the basis for assessing impact.

2. Changing the size of patches - Patch size has been predicted as a determinant of species diversity on the basis of island biogeography theories (MacArthur and Wilson 1963, 1967). These predictions have been substantiated for flora (Tramer and Suhrweir 1975; Elfstrom 1974) and for avian fauna (Galli et al., 1976; Whitcomb 1977). Maintenance of mesic conditions in the interior of disjunct patches that permits development and maintenance of mature forest depends on their exceeding a threshold size of about 2.5 ha (Levenson 1976).
3. Changing the isolation of patches - Island biogeography posits that species richness of a patch is inversely proportional to its distance from large blocks of natural vegetation that can serve as sources of propagules. This has been borne out for isolated forest patches in the Midwest (Tramer and Suhrweir 1975). The species composition of the seed rain that maintains seed pools in patches is a function of patch isolation. The impact of isolation changes with the successional status of the patch because some species are better adapted to migration between patches than are others. For instance, the bird-dispersed black cherry is better adapted to colonization of isolated woodlots in Wisconsin than is the wind-dispersed sugar maple (Auclair and Cottam 1971). Patch isolation should not exceed the dispersal capability of the least mobile desired species.
4. Patch shape changes - Patch shape, as measured by perimeter/area ratios, affects the microclimate within the patch (Gysel 1951; Wales 1972). This becomes an increasingly important consideration as patch size approaches a threshold, as discussed previously.
5. Topographic selectivity of patch maintenance - The probability of regional extinction of a species is inversely proportional to the variety of habitats available to it (Whittaker 1953). Therefore, maintenance of natural patches on a variety of sites tends to reduce the probability of species extinction.
6. Age of patch - Patches of mature vegetation, e.g. late successional forest, are more valuable than early successional patches in a man-dominated landscape. They are likely to have species not shared with many other patches and therefore are valuable as refugia and as centers for migration to other natural patches. Forest ecosystems with highly integrated soil/biotic relationships evolve over centuries. Remnants of long-standing natural vegetation are virtually irreplaceable in the human time frame.

Application of Principles

The principles just stated are most readily applied to landscape level units on the order of 1-16 km², or to specific patches of natural vegetation, e.g., woodlots. Projections of impact of energy development on such large blocks of natural vegetation as parks and preserves should also invoke these principles. Consideration of larger-scale impacts, at the level of Federal Reserve Districts, ecoregions, or the nation, is based primarily on aggregation.

Current research on the diversity of patterns of remnant natural vegetation throughout the eastern U.S. will lead to a classification of patterns that will be useful in assessing impacts. A preliminary evaluation of regional types whose patch mosaics are especially sensitive to energy development can be made, however. Two types of immediate impacts are possible: those that remove all natural vegetation from a site, such as a strip mine or power plant; and corridor developments such as powerline rights-of-way or the railroads or highways that might be projected under some energy scenarios. The first impact is intense but local, and involves removing patches and refugia from the landscape. The second impact is more likely to be significant since it could have the dual effect of destroying specific patches or changing their size and shape (such as bisecting a large patch) and of altering the functional isolation of patches by either imposing a barrier to animal movement or providing new corridors for movement between patches. Both impacts are affected by the density of natural patches in the landscape.

Largely natural landscapes may not be affected by corridors even though natural vegetation is removed along their entire length, because a sufficient portion of the mosaic remains to maintain regional ecosystem functions. This statement does not consider the effect of corridors on species requiring large tracts of undisturbed vegetation, but these are highly localized regionally. At the other extreme are areas, such as the Corn Belt, already so depauperate in natural patches that the probability of removing a remnant patch of natural vegetation or of reducing currently high levels of interpatch movement is low. Corridors can be designed to avoid the few remaining critical areas. Regions that are most likely to be sensitive to corridor developments are those with intermediate proportions (20-50%) of the landscape in natural vegetation. Corridors would tend to fragment existing large blocks of natural vegetation and/or affect interpatch movement. In general, the most sensitive regions have a large proportion of rural land of intermediate agricultural value.

Data Availability

Few data that are relevant to energy development considerations are available on patch mosaics, but they are being acquired under current research. County-level data bases cannot be disaggregated to assess landscape patterns. However, those counties with the intermediate proportions of natural vegetation mentioned before should be given priority for more local studies.

However, data bases that show landscape patterns are available for limited areas. The Tennessee Valley Authority has spatial data bases for a number of areas in the Tennessee Valley. The areas covered are at the county level, and the resolution is 1-40 acres in most cases. These data bases have proven invaluable in assessing impacts of corridor developments. The effort involved in developing such data bases makes a classification scheme for landscape patterns an important potential tool for environmental assessment at the regional and national scales.

4.8 SPATIAL AND TEMPORAL SCALE CONSIDERATIONS ASSOCIATED WITH DYNAMIC OSCILLATION AND CYCLING REGULATION WITHIN ECOSYSTEMS

The direct effects of an energy system on an aquatic ecosystem are generally confined within a body of water. Where the point of impact is near the lower boundary of an ecosystem (e.g., where a river discharges into a lake or estuary) spillover effects may be expected on the downstream ecosystems. However, in the more general case, the effects of increased turbidity, thermal discharge, selective cropping, and even flow reduction will be predominantly realized in the body of water where the disturbance enters. Thus the body of water will become the basic unit of spatial scale for energy-development impact assessment.

The one exception to this generalization, which should be of major concern to DOE, is associated with migratory commercial and game species, and especially the major anadromous species (e.g., salmon and striped bass). Impacts on key elements within the ecosystem at certain locations along the migratory path can significantly affect the population of migratory species and, thus, transmit impacts to both upstream and downstream bodies of water and ecosystems. As an example, the thermal discharges from two power stations along the upper reaches of San Francisco Bay have shifted the time of bloom of the spring algae. The result is a reduced food supply for downward migrating young-of-the-year striped bass. The resulting impact on the striped bass population is felt in subsequent years both as a reduced fishery yield and as an impact on the upstream delta system in the striped bass spawning areas. Although the primary human interest is in the population effects, the power plant impact is transmitted through that population into ecosystems not directly affected by the power plants. This potential must be considered in defining the spatial scale to be addressed during the impact-assessment process.

Although the principles governing considerations of temporal scale are the same for aquatic and terrestrial systems, the resulting assessment time scales are generally different. Within the waters of the U.S., perturbations can be transmitted through the aquatic ecosystem, and the resulting system responses can be measured over a relatively short period of time (weeks or months for local impacts to several years for major population impacts). This is not generally true for terrestrial systems, which tend to show their responses through production losses for some species or through successions from one species or set of species to another over a relatively long period of time (detectable over a decade, significant over a 50 to 100 year period).

Similarly, the system-recovery time after cessation of the stress tends to be compressed for aquatic systems. This time is primarily a function of the pollutant residence time, or, conversely, of the system's flushing time, and of the availability of replacement populations in adjacent ecosystems. The fluid mobility of aquatic systems, therefore, tends to enhance system recovery and to increase the reversibility of energy-related impacts.

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APPENDIX C

PROCEEDINGS OF A WORKSHOP ON NATIONAL/REGIONAL
ENERGY-ENVIRONMENTAL MODELLING CONCEPTS

Reston, Virginia

May 30 and June 1, 1979

Energy Analysis Program
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

July 1979

Sponsored by
Assistant Secretary for Environment
U.S. Department of Energy

TABLE OF CONTENTS

	<u>Page</u>
Introduction.....	C-2
Keynote Address.....	C-3
Perspectives on Modelling.....	C-5
Working Group Report (1): Model Structure.....	C-9
Introduction.....	C-9
Recommendations.....	C-9
Long-Term Recommendations.....	C-10
Short-Term Recommendations.....	C-12
Summary.....	C-13
Working Group Report (2): Measurement Issues and Approaches.....	C-14
Introduction.....	C-14
Data Systems and Sources Recommendations.....	C-15
Procedural Recommendations.....	C-16
Summary.....	C-18
Working Group Report (3): Use of Models for Policy Analysis.....	C-19
Introduction.....	C-19
Recommendations.....	C-19
Regional Involvement in Assessment Process.....	C-19
Design of Assessment Program.....	C-21
Relationship of Modeller and User.....	C-23
Summary.....	C-25
Table 1 - Summary of Workshop Recommendations.....	C-26
List of Participants.....	C-28
Appendix I: Essay on Data Quality, Model Complexity and Uncertainty.....	C-30
The Data.....	C-30
The Model.....	C-30
The Application.....	C-31
The Results.....	C-31

INTRODUCTION

On May 30, 31 and June 1, Lawrence Berkeley Laboratory, under the sponsorship of the Office of Technology Impacts (OTI), U.S. Department of Energy (DOE), held a workshop at Reston, Virginia on national and regional modelling. The workshop, entitled "National/Regional Modelling Concepts for Energy and Environmental Analysis", brought together 35 experts from a wide range of disciplines including energy and economic modelling and several aspects of regional sciences. Appendix A presents the list of participants for the three day meeting.

The purpose of the workshop was to identify and evaluate approaches to regional economic and energy supply/demand forecasting that are best suited to assisting DOE in the assessment of environmental impacts of national energy policies. Specifically, OTI uses models to assess the impacts of technology change, to analyze differential impacts of various energy policies, and to provide an early warning system of possible environmental constraints to energy development. Currently, OTI employs a "top-down" model system to analyze national scenarios and a "bottom-up" assessment conducted from a regional perspective. A central theme of the workshop was to address the problem of how OTI should integrate the "top-down" and "bottom-up" approaches. The workshop was structured to use the experience of many fields of regional analysis toward resolving that problem.

The format of the workshop provided a flexible structure emphasizing small working groups. The first day of the workshop consisted of a plenary session which began with a keynote presentation by Peter House, Director of OTI. After a brief discussion period several different perspectives on energy and economic modelling were presented. The aim of these presentations was to examine the modelling experience in several fields of regional analysis and to focus subsequent discussion by the subpanels. The organization for the remaining two days including the composition of the working groups and their general topic area evolved from the presentations and discussions on the first day.

During the second session the participants were divided into three subpanels which addressed specific topics related to the overall objective of the workshop. The topics of the subpanels were: measurement issues and approaches, structure of models, and application of models to policy analysis. The working group members were responsible collectively for developing a list of recommendations on their assigned topic during a day-long discussion period.

The last day was a plenary session in which the reports from each of the working groups were presented. An open discussion period followed each presentation and provided an opportunity for further elaboration and refinement of the specific issues and recommendations produced by the workshop participants.

The proceedings are organized into three major sections. The "Keynote Address" contains the presentation by Dr. Peter House. The section entitled "Perspectives Modelling" includes a brief description of each of the seven presentations given during the opening session followed by a summary of the discussion period. Finally, "Working Group Reports", contains the recommendations and conclusions prepared by each subpanel. An attempt is made to incorporate the working group findings into a final set of recommendations which appear as Table 1.

KEYNOTE ADDRESS

The terms "top-down" and "bottom-up" sound like something which would be banned in Boston. In this instance, the terms refer to different conceptual approaches to model development (although this too might be banned in some quarters). The beliefs and strategies of proponents of these approaches often make for interesting reading and have provided entertainment at several professional meetings. They also suggest information capabilities of different types that are needed in formulating national policy. It is this latter subject which interests us now.

Top-down analysis suggests methodologies which attempt a more global perspective of the relationship between variables. Normally, the analyses produced are relatively holistic in nature, and attempt to investigate strategic questions of national policy. Data are collected at a relatively coarse grain (state or Federal regions as opposed to city block), and relationships between the variables are represented by average coefficients rather than by specific activity levels. These models are used both for research and analysis purposes to test first order consequences of various strategy alternatives and to look for unanticipated effects of various courses of action.

Bottom-up analysis normally means the integration of the results of a series of detailed analyses to produce a complete national or global picture. These individual analyses, in contrast to the above, are more detailed and represent more clearly the specific areas or portions of a problem. Such analyses are often used in assessments of national strategies where time and resources allow a more detailed survey. Often issues of a less analytical nature are introduced into these analyses. The data and relationships modelled in these studies are of fine grain and might, for example, contain spatial analyses locating impacts of various policies in a more precise fashion.

The debate which occurs when one tries to assess the relative merits of one of these approaches over the other rings hollow when it is taken out of the intellectual arena and finds its way into real life policy issues. It becomes clearer then that there is no simple-minded response to which of these approaches is "best". Obviously, it depends on a whole series of factors: the specific policy, time and resources available, where the decision is being made, and so forth. In the best of all possible worlds, however, one would hope that an agency would have both types of models available. The results of a top-down analysis could be directly utilized by the family of models using a bottom-up methodology, and vice versa.

This capability would allow an agency to utilize the analysis produced by the more macro approach as a bounding condition of micro models. To some extent, this suggested technique solves the problem of too general and regionally insensitive results obtained from the top-down models, but does impose a tyranny of total value limits on the bottom-up segments. The latter is important since the essence of the bottom-up approach is that the totals are "discovered" by summing up the values obtained in the several detailed studies, and the aggregated totals may not equal the discovered totals.

A true bottom-up approach is likely to be less than totally useful to Federal policy makers if their use is meant to be repetitive and on a relatively short time demand. The organizational and administrative problems of continually exercising such a network would likely be impossible or at least a feat of impressive skill. Further, there is an inherent weakness in producing unbounded partial analyses of policies as each study area makes up its own mind as to the share of the total policy or impact it will have or cause. The so-called "chamber of commerce" effect often noted in areas such as geographic analyses where local bias creeps into the results and the integrated impacts when calculated are far greater (or less) than could realistically be anticipated.

For these reasons, I would suggest that the Workshop concentrate on the problem of mitigating the worst deficiencies of the top-down approach by enriching the macro analyses with more specific studies. For those who disagree with these suggestions, however, feel free to pursue alternative avenues.

Of particular interest are the answers to questions of the following sort:

- o Can there conceptually be a successful integration of the top-down and bottom-up approach? If yes, what would each of these systems contain? How would they link?
- o Institutionally, how would one house, care, and feed the system of models and analyses that the above design would portend? Where should it be housed, inside, outside the government or some combination? How does one go about running all or part of this system for analysis? How does one decide what parts to run for what analysis?
- o Administratively, what should such a system cost: to build, to run, and to maintain? Should it be the captive of only one agency?
- o Specifically, how does one go about demonstrating the validating of the results obtained from the system? How do you improve it?

These questions are hardly exhaustive and are meant only to provide a start for you in your individual task groups. The problem is very difficult and the implementation no doubt as difficult, but if it can be done and can be demonstrated to give superior answers to our increasingly complex policy issues, there is little doubt it will be used. You represent a collection of some of the better thinkers in these fields and know of the difficulties before you. Your presence here suggests that you have accepted the challenge.

PERSPECTIVES ON MODELLING

The following perspectives on modelling were presented by seven participants representing a variety of economic, energy and environmental disciplines. The speakers were chosen to provide background and experience for the subsequent discussions of modelling approaches. Two of the presentations were by OTI staff to provide background on OTI's modelling effort and policy concerns.

Roger Shull, Director, Environmental Impacts Division, Department of Energy

Roger Shull reviewed the DOE/OTI Policy Impact Assessment Program. The major programs of OTI involve national simulations as well as analyses of regional variations in environmental quality. He emphasized use of the SEAS model which is a "top-down" approach, with economics calculated using a 200-sector national input/output model. The results are disaggregated to the Federal regions and states and to about 650 processes. Environmental impacts are calculated for the 650 processes at the state level and allocated to determine local impacts. One of the major problems, according to Shull, is that where ten years ago the problem was to evaluate policy questions quantitatively, there are now so many quantitative approaches that they themselves must be evaluated.

Summary of Discussion

A question was raised about which models have been validated and could be used as a nucleus for building a system of models in which decisionmakers had confidence. It was stated that the purpose of a model is to prevent bad decisions, not to predict the "correct" answer in the future.

The discussion centered on whether there are any good regional models and where they are presently housed. A comment was made that OTI send their results from the SEAS model to the national laboratories for further regional analysis. The final discussion related to the economic modelling capabilities of the national laboratories. The problem of national/regional interface may not be related to the existing models but to the interface of the organizations.

Richard Ball, Environmental Impacts Division, Department of Energy

Richard Ball presented the SEAS model in more detail. The calculations start with national level policy variables and technology characterizations. Energy supply/demand balances are calculated regionally using the MEMMS (revised PIES) model. These balances are inputs into the SEAS input/output model (INFORUM) which generates activities and pollutants, that are then disaggregated to determine the regional discharges. Finally, using estimates of the population at risk and the local ecology, environmental and health impacts are evaluated.

Summary of Discussion

There was a brief discussion of what variables are sensitive in policy analysis. It was pointed out that the inputs to models come from many levels. The level of geographic detail over time was identified as an important parameter.

Walter Isard, Cornell University

Walter Isard noted that a policy represents constraints on a model. These constraints are used as inputs to models which then can estimate the impacts. Isard summarized the modelling techniques that might be used in constructing a model useful for policy analysis. These techniques include: (a) cost models for energy-using industries based on location theory. The capital requirements would feed into a (b) multi-regional input/output model with (c) pollutant coefficients. This would produce the (d) energy requirements by region and sector. By identifying the sources of energy supply one could build an (e) energy transportation model(s). Finally, the (f) local pollutants from the various energy supply facilities can be calculated. The theme of Isard's presentation was that many models are currently available (e.g., multi-regional input/output, econometric, linear programming, etc.) that can be linked together in order to solve the national/regional integration problems.

Summary of Discussion

Several problems with this approach were discussed. First, the nodal demand concept (i.e., concentrating demand in one place) may not be realistic for most energy transportation models. The transportation costs and modal splits will not be handled properly. Secondly, it was questioned, whether this approach is predictive or only used for comparing alternatives. It was felt that the location theory models for industry were predictive and that I/O models were also predictive over a limited time horizon.

It was pointed out that this sort of "top-down" approach was appropriate for all problems. General policy can be done by "top-down" models but local impacts require some type of "bottom-up" approach. A model of this size requires a large commitment for data acquisition and updating. Discussion centered on who could use the model and for what purpose.

Finally, it was noted that I/O models can help to show if a scenario is feasible in terms of resource availability and impacts. Further, these models can be used over a longer time frame if the coefficients are modified to reflect changes in technology.

Edward Quade, formerly of RAND Corporation

Edward Quade presented a historical view of modelling based on his earlier studies for the Department of Defense and RAND Corporation. He pointed out some of the pitfalls of using models for policy analysis. These included: defects in the model structure, implementation of the results, development of the models, data and information needs, and interpretation of the results.

Quade cautioned that modelling is only one aspect of policy analysis. Models do not always consider non-quantifiable factors such as equity, participation in decisionmaking, and other social impact areas. Furthermore, the models are usually biased by the values of the modeller.

He recommended use of small, simple models that are linked together. As an example, Quade mentioned a San Diego pollution study conducted by RAND which uses 10-15 models that are linked together. These models are used to produce a matrix of impacts in relation to various policies.

Summary of Discussion

The discussion addressed the bias problem which some participants believed could be solved by using rival models and comparing the results. It was concluded that the assumptions used in constructing any model should be stated explicitly. Finally, the question was asked whether we need bigger and better models. It was felt that the modelling techniques are much further advanced than the available data so that data often become the limiting factor.

William Marcuse, Brookhaven National Laboratory

William Marcuse began by noting that no policy analysis models are predictive. They give a systematic structure for comparing technologies and policy alternatives. Marcuse provided a summary of the various modelling approaches. He discussed models under the following categories: aggregation and disaggregation (e.g., hierarchical, interdisciplinary, intertemporal), model selection (e.g., linkages, intertemporal considerations), and kinds of models (e.g., econometric, process, behavioral).

Finally, he described two hierarchical structures in which one can enter the model at any level. Marcuse believes that process models are useful in evaluation of policy options. Most process models can look at current stock, processes and trends in order to forecast new energy sector coefficients. Institutional problems, however, are not handled well in either econometric or process models.

Summary of Discussion

The discussion centered on whether OTI was doing predictive or comparative assessments. It was stated that the models and analytical systems should not be used as predictors, but as comparative reference systems against which a set of scenarios is compared. Even though there was ample justification given for the scenario approach, there was some discussion as to whether that methodology is the best. Finally, it was noted that DOE needs generalized methods and techniques for addressing a wide range of policy questions.

Robert Wendling, Bureau of Economic Analysis, Department of Commerce

Robert Wendling described the "bottom-up" modelling effort at the Bureau of Economic Analysis. This system termed the National-Regional Impact Evaluation System (NRIES), is designed to estimate the spatial distribution through time of impacts resulting from policy alternatives. The model may also be used for medium-range (5-10 years) forecasts of regional economic and demographic activity. While the model has no pollution parameters, pollution abatement expenditures are implicitly internalized and measured by the estimation procedure.

NRIES consists of 51 state econometric models integrated into a national framework. Because of the model's unique bottom-up structure, the overall level and regional distribution of economic activity in the Nation are simultaneously determined. There are several advantages to the approach employed by NRIES. First, because one of its elements is an interregional model, NRIES can be used to analyze the regional or spatial distribution of policy impacts. Second, the system simultaneously determines the level of both national and regional activity. Third, by integrating regional and national models, the NRIES structure insures that the sum of regional activity is consistent with reasonable forecasts of national activity. Finally, NRIES is able to examine the effects of concurrent national and regional policy changes.

Summary of Discussion

The discussion revolved around specific features of the model such as how the cost of pollution control is incorporated and whether the system considers the sulfur content of coal or other fuels. The general question was raised about the appropriateness of econometric models when conditions were changing so rapidly. The model was characterized by some as merely an impact assessment model and not a forecasting or scenario evaluation model. Wendling gave examples of how NRIES can capture certain impacts which a typical "top-down" (nationally controlled) model could not. It was questioned whether regional estimates are better than state and if potential state errors are cancelled out at the regional level. The reply was given that national totals are more accurate but that data and calculations are at the state level. Currently, the Energy Information Administration is attempting to couple this system with an energy demand forecast.

T.R. Lakshmanan, Boston University

T.R. Lakshmanan discussed classes of policy questions. He distinguished between short term policy issues which involve specific tactics (e.g., the gasoline crisis) and longer range strategic questions (e.g., the best technologies for R&D). Each class of policy question would probably require an appropriate set of models.

Lakshmanan then outlined an approach for integrating national and regional models. Since most large organizations similar to DOE typically have a decisionmaking hierarchy, he proposed a multi-level, multi-objective system. The structure of this system included spatial, functional and intertemporal components. The hierarchical organization is composed of vertical arrangements of subsystems where higher level units have some priority of action over the lower level ones. However, these higher and lower subsystems are interdependent and require information flow between them. He described the obvious problems of data and information flows between the various levels. Finally, he noted that the model-building process is usually "top-down" in which one proceeds from a formal system to a conceptual model and then to an empirical model with quantitative relationships and simulations.

Summary of Discussion

There was discussion about the coordination between agencies concerning the use of models. The consensus was that there is little coordination and there are problems with documentation and consistency among models. Further, the documentation is usually lacking for data and model systems. About 25-30 percent of the total cost of any analysis or model development program is for documentation and this aspect is often not funded.

WORKING GROUP REPORT (1):

MODEL STRUCTURE

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Jayant Sathaye, Editor
Richard Ball
Robert Bolling
Richard Goettle
Curt Harris
Hubert Hinote
Walter Isard
John McLeod
George Treyz

Introduction

The model structure group, one of the three groups set up during the workshop, convened for roughly a day and a half with ten participants and several observers taking part in the discussions. In summarizing those discussions here, we have attempted to include all the varied but significant viewpoints expressed by participants in the group. As such, every viewpoint expressed does not necessarily represent a unanimous opinion, although the central theme of the discussion regarding long-term and short-term recommendations was generally agreed upon by the participants.

Model organization and emphasis are usually oriented along influence directions and are dictated by constraints placed on them. In economic-energy-environmental models (EEE), these constraints and influences are imposed both from the national and the local level. Hence any realistic model designed to embody all major behavioral phenomena relating national/regional local policies and dynamics of economics and environmental activities must be organized with bi-directional constraints or influences. It was therefore the view of this group that interlinked models that capture this two-way informational flow be implemented both in the short and long term.

In this context, the feedback loops become very critical. The manner in which this feedback is communicated, whether by machine or by man, will also decide the accuracy, bias and speed with which policy questions will be analyzed. It was pointed out that the feedback loop, so common to economic interaction often does not exist in environmental modelling where the obvious directional constraints operate from the top down. For example, an aquatic ecosystem model of food uptake would have only a weak feedback from the fish, algae and so forth. However, for EEE modelling a top-down and bottom-up approach is essential to adequately capture all the interactions.

Recommendations

There was general consensus in the group that a multi-level modelling system built around a unified national-regional accounting framework was the correct way to analyze energy-economy-environmental interactions. The group recognized that several integrated EEE models exist and are being used actively within the Department of Energy. Each model system embodies a combination of several analytical techniques to answer specific types of policy questions appropriate to the agency functions. One of the important functions of the Office of Technology Impacts (OTI) within Assistant Secretary for Environment (ASEV) is to assess the economic and environmental impacts of energy-economy projections.

In the context of policy concerns and policy analysis responsibilities of ASEV, the work group addressed improvements called for in existing analytical and information techniques. Separate improvements were suggested for short-term and long-term modelling efforts. The short-term recommendations generally suggest changes in the current Strategic Environmental Assessment System (SEAS) methodology and in its linkages with other models. The long-term improvements call for a new modular methodology with an integrated accounting system.

Long-Term Recommendations

Recognizing that modellers have had several years of experience in dealing with energy-environment-economic models employing different analytical techniques, the working groups recommended the following:

o Advisory Group

An advisory group of expert individuals be established to further investigate and suggest an appropriate methodological framework in which to analyze a broad set of policy questions. The group would be responsible for designing a core configuration of models and the information system needed to make these models practicable. Earlier in the discussion it was apparent to the group that it would not be able to decide on the exact type of long-term model because of the short duration of the workshop and because of an incomplete understanding of OTI functions and responsibilities. However, it was clear that it would be relatively easy to delineate the essential attributes that such a long-term model system should have.

o Modular

It was recommended that a core set of relatively simple analytical and informational systems be established in contrast to a single complex model. The system should be such that modules for analyzing different impacts could be detached or attached with relative ease. The system would be modular in its choice of sectors, geographic regions, and impact areas.

o Consistency and Accounting Framework

Consistency among different models and accounting frameworks was deemed essential in providing reliable comparisons of different energy projections. One way to insure such a consistency would be to base the core set of models on an interindustry accounting framework with built-in mechanisms for aggregating or disaggregating the sectoral and geographic breakdown. Some of the advantages and disadvantages of the Multi-Regional Input-Output (MRIO) approach were discussed in this context. The accounting framework provided by MRIO was deemed highly desirable although the specific models and their uses appeared inadequate or questionable.

The set of models currently in use have certain built-in interdependencies between energy, the economy and the environment. None of the models appear to have consistent linkages between these three areas. The recommended core set of models would need to be planned carefully and reviewed to provide consistent and comprehensive linkages at the sectoral and geographic level of detail. Furthermore, the core models would undoubtedly include elements using different analytical techniques representing various approaches. It was felt that a proper combination of these techniques would significantly improve the analytical range of the core system. Four approaches were mentioned in this context: econometric models, process models, input-output models, and location theory models. Econometric analysis was deemed suitable for analysis where existing economic relationships were likely to hold. The technique may not be suitable for long-term analysis unless augmented by models of technological choice. For long-term analysis, it is essential that the parameters which form the basis for such an analysis be stable and that the relationships

hold for the future or at least be predictable. For example, in the MRIO framework, the trade coefficients are very unstable and may not hold for the future, whereas the technical coefficients are comparatively stable and can be updated. Location theory was advocated as one of the techniques which would be used to avoid the problems of predicting trade flows as well as to serve as the major basis for the core model.

o Dynamic

The planning and review of the core model system ought to be a continual process where both the modelling techniques and data bases can be updated. This may require changes in technical and location coefficients as well as in geographic and sectoral detail. Further, the sequence of disaggregation -- whether to break down into geographic detail first and then analyze the sectoral detail or do the sectoral detail first and then disaggregate by geographic regions -- merits additional research.

o Regional Interaction

The core set of models could provide an effective means of communication among modellers in different regions or among modellers specializing in different sectors of the economy and the environment. The organizational and management problems inherent in such a system of models were also recognized as a non-trivial problem. For up-to-date and reliable information, it was felt necessary that regional entities be involved in such a system. This would permit regional entities to communicate through computerized models or through other organizational structures. The choice of such entities in each region is important to soliciting an unbiased and quick response and to avoid the so-called Chamber of Commerce effect which allegedly plagued the Office of Business Economics and Economic Research Service (OBERS) forecast. Technology sets for production and consumption by each region are one of the critical items in formulating a core set of models. The regional definition at which the set of models would form a consistent accounting framework and have such technology sets was disputed although the state boundaries were advocated as the appropriate level. Other regions mentioned included the Bureau of Economic Analysis (BEA) areas, counties and Federal regions.

o Documentation

Lack of adequate up-to-date documentation was pointed out as one of the key deficiencies in understanding the various large modelling efforts being conducted in DOE. Recognizing that a major part of the effort would go into documenting the core set of models, it was recommended that a substantial effort be put into clearly identifying the assumptions, data bases and the linkages.

o Implementation

One way of implementing such a long-term set of models was outlined during the discussion. It consists of several steps which were generally agreed upon:

- (1) Provide a natural language description of the model including all the constraints and influences existing in the system being modelled.
- (2) Document the description and have it reviewed by experts both internal and external to DOE.
- (3) Determine the variables and parameters necessary to simulate the system.
- (4) Develop a flow chart delineating all the linkages and functional processes.

- (5) Outline the data requirements by sector, geographic region and impact area. Collect data and estimate the parameters.
- (6) Write a program for a relatively simple aggregated model.
- (7) Check with experts and the client to ensure that aggregations do not over-simplify the model.
- (8) Perform sensitivity tests on the model to indicate where data needs to be refined or the model could be modified.
- (9) Plan simulation experiments to examine the policy questions of interest to the client.
- (10) Analyze results and recommend reformulation of the model.

Some of the steps outlined were questioned in light of real life experience with EEE modelling. The results provided by these models are difficult to check against any criteria or guideline established to evaluate them. Also, an aggregated rough cut model has to be credible to begin with, otherwise the policy analyst is likely to have little or no faith in it.

Short-Term Recommendations

Short-term recommendations focused primarily on the existing SEAS modelling capacity within OTI. The SEAS model was generally described to the workshop participants, and several areas where deficiencies are apparent were brought out. The SEAS model as operated by OTI used the Interindustry Forecasting at the University of Maryland (INFORUM) input-output model as the major driver for estimating economic and environmental impacts (residuals, emissions, etc.). It is also coupled with the energy demand/supply projections made by the Energy Information Administration (EIA) using the Data Resources Incorporated (DRI) and Midterm Energy Forecasting System (MEFS) systems. The differences between MEFS and SEAS are the first source of inconsistency in the modelling capability.

Within the SEAS model, several inconsistencies were noted. The siting and population demand models are not linked, nor is there any linkage between energy industry and population location models. County industry location does not have any relation to energy demand and industry does not respond to changes in energy prices; the model lacks the flexibility to answer different types of policy questions.

Questions were raised about the necessity of the large 650 sector process detail in SEAS models considering that it is based on a roughly 200 sector INFORUM national input-output table and 29 sector OBERS breakdown. It was pointed out that the large number of sectors in an input-output model reduces the error in assuming national technical coefficients at the regional level.

It was generally agreed that SEAS has the requisite components of a desirable EEE structure for conducting a top-down impact analysis. However, there are some major areas which need to be addressed.

- o Base year data needs to be improved at both national and regional levels.
- o Accounting framework needs to be improved in the area of energy-economy interactions.

The top-down SEAS approach needs to be supplemented by a bottom-up approach. One way to achieve this would be to follow the existing system, letting the national laboratories respond to SEAS results based on their analysis at individual Federal region level.

Summary

The model structure group concluded that top-down and bottom-up approaches are both essential to adequately represent all the interactions in energy-economic-environmental modelling. The group also recommended establishing an advisory group of expert individuals to investigate an appropriate framework for long-term OTI modelling activities. Attributes essential for a long-term core set of models were explored and delineated during the discussion. Short-term recommendations suggested improvements in accounting framework and in the basic year data bases of SEAS.

WORKING GROUP REPORT (2):
MEASUREMENT ISSUES AND APPROACHES

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Introduction

Development and application of formal models in analysis of the environmental and socioeconomic implications of alternative energy policies is ultimately restricted by our ability to obtain implementing data through measurements on the underlying reality being modelled and analyzed.

The purpose of the Measurement Issues Working Group was to review the current status of measurement systems providing data for policy research and modelling in this area, and to recommend actions to improve the further development of these systems, as well as to improve their use. Our recommendations fall into two areas, including (1) data systems and sources, and (2) procedural recommendations.

In our analysis we have avoided discussions of particular modelling approaches and methodologies although we recognize that to some extent modelling approach may determine data needs. We have also tended to focus upon comprehensive and continuing measurement systems as contrasted with special purpose efforts intended for particular, perhaps narrow, applications.

As an aid to our analysis, we have constructed a paradigm of the analysis problem facing OTI which we employ in identifying key measurement issues. Our paradigm is as follows. OTI is responsible for analyzing the environmental and corresponding socioeconomic effects of specified energy policies. These analyses may range from impact assessments for a particular technology (residential applications of photovoltaic-based technologies) to general assessments of a complex national energy policy. Regardless of scope, these assessments are basically differential in nature, involving a projection of how the socioeconomic-environmental system will change due to the particular initiative being considered. The analysis problem is, therefore, twofold: (1) to understand and project the relevant system performance at the level of detail required by the analysis without the policy initiative; and (2) to interpret and analyze the implications of the policy initiative at the necessary level of detail, and to aggregate to levels appropriate for calculating and interpreting the differential effects.

The great difficulty in following this approach is that the detail of the socioeconomic and energy production, conversion and consumption measurement systems do not correspond to that required for the environmental impact analysis so that (1) we cannot produce the reference case at the necessary level of detail; and (2) we do not have real data to analyze and model the detailed interactions which produce the differential effects we seek to calculate. It should be noted that lack of detail goes beyond geographic classification. Perhaps of equal importance are activity classifications, process detail, fuel types and quality.

The essential point is that, as so many modellers lament, the data simply do not currently exist to close the loop in the analysis process we have described. Our working group makes this fact its point

of departure and attempts to develop recommendations to improve this situation, cognizant of both the importance of the problem and the limits on resources and possibilities for expanding present measurement systems. An introductory essay is presented in Appendix B which discusses the relationship between data quality, model complexity and the degree of uncertainty in the results.

Data Systems and Sources Recommendations

- o OTI must attach a higher priority to developing, maintaining and extending an integrated system of socioeconomic, energy, and environmental effects accounts.
- o OTI must interact more effectively with EIA and other statistical agencies to ensure sufficiently detailed energy production, conversion, transportation, and consumption data are available for use in its assessment models.

One of the problems in analyzing the socioeconomic and environmental impacts of energy policy initiatives is the lack of connectivity between the separate measurement and accounting systems that provide the basic data for modeling and analysis. Most disturbing is the fact that survey systems for acquiring energy production and consumption data are unrelated to those used in acquiring environmental effects data. The current inability to make these data systems congruent greatly complicates the modeling and analysis process.

The working group recommends that OTI work closely with EIA in setting up a system of national and regional energy accounts which would be consistent with the accounting system used for economic data. One of the important tasks is to define the categories and coverages of energy production and consumption data that are required for the energy policy analysis that OTI conducts. Specifically, the areas of concern are the industrial sector, location, fuel type, end use, and quality (e.g., temperature) of the energy. Furthermore, OTI should assist EIA in formulating special studies designed to provide the more detailed data needed for modeling specific locations or technologies.

- o OTI should acquire detailed environmental and technology characterization data for statistically representative geographic units, processes, end uses, fuel type, and quality (e.g., temperature). In general, increased use of statistical sampling to augment census survey data is recommended.

Although in principal, data are available at the level of detail needed for most impact analysis, practical constraints -- time, money, resources -- limit the amount of data that can be collected by survey techniques. The problem becomes more difficult as one goes from economic to energy to environmental data because the dimensions of the data increases. Moreover, as the data amount of information requested in a survey increases, the quality of response may actually decrease because of the large reporting burden on the respondent. As a result, the data available to the modeller are not sufficiently detailed to be useful in analyzing impacts at the level required for policy analysis.

OTI should complement its SEAS program with highly specialized individual regional studies. For this purpose, a range of representative regions, technologies, processes, end uses, etc., should be selected. Adopting this practice would permit the gathering of specialized environmental and related data at moderate cost, thus facilitating in-depth analysis that could be generalized to similar regions. Such data may be available through EPA. OTI should coordinate with EPA in the collection and compilation of environmental data needed for detailed impact analysis. It should be emphasized that by using statistical sampling techniques for selecting the representative units, it is possible to combine the sample and survey data and thus generalize the results obtained from the specialized studies.

An in-depth data collection effort of limited geographic scope would permit the tailoring of analyses in light of the individual issues and technology characteristics. It would relieve OTI of the need to collect data for every variable in a nationally consistent format and would permit more detailed examina-

tion of smaller issue areas. This contrasts with the current practice based on the top-down accounting methods, and would restore a balance between national and regional issues to the OTI analytical program.

- o Statistical estimates of the uncertainties in the environmental and economic effects must be included both in the data used in calculating the parameters of the assessment models and in presenting model-based results.

The numerical results from models that are used in setting policy action were presented without any indication of the reliability of the results. Without knowing how accurate these numerical values are, the analyst cannot tell whether the differences he obtains are statistically significant. This difficulty arises because the accuracy of the data used in the model is often not known, or if it is, the models are so complex that the uncertainties in data are not easily translated into uncertainties in results. The working group realizes that some uncertainties such as those due to model structure are not quantifiable because of a lack of complete theoretical understanding of the phenomena being modelled.

Quantification of the uncertainties associated with modelling and analysis should be ardently pursued using actual measurement statistics, results of validation studies, or ad hoc parameterization (in order of preference). An important prerequisite for this is that the statistical uncertainties associated with the data used in the model be presented along with the data.

The uncertainties in the final results will often yield policy conclusions of the form: "within the limits of the analysis there is no discernible preference between these alternatives." This is an unacceptable result. It is far more acceptable than an erroneous and statistically insignificant finding that just serves to cloud an already murky political debate. When a clear and statistically significant reason for choosing a particular alternative emerges, the conclusion is far stronger when it emerges from a source credible enough to be able to say "I don't know" to impossible questions. OTI currently does not have this capability. It is unreasonable to always expect models to provide all the answers. Explicit recognition of this fact will serve to reinforce the contributions that modelling techniques and modellers can make to the solution of the policy problems.

Procedural Recommendations

- o Current and prospective programs for acquisition of socioeconomic, energy and environmental effects data do not support comprehensive modelling systems. New modelling efforts should tend toward simpler models congruent with real measurements and should not rely on "synthetic" data.

The models that OTI currently uses for policy analysis are quite complex with a high degree of regional and sectoral disaggregation. The quality of the currently available data and of the data that might be available in the foreseeable future is not adequate for so detailed a model. These models are inefficient in the sense that the effort has gone into achieving that level of detail, for example, into generating "synthetic" data, could be more effectively applied to acquiring fewer but better quality data for a more simple model. Many of the results of these models are based on the presumed detail in the data which, on closer inspection, is not really there.

The relationships between data quality and model complexity as discussed in Appendix B suggest two complementary strategies that OTI might use to enhance its analytic capability. One is to forego any additional increase in SEAS model complexity (e.g., more sectors or more disaggregation procedures) in favor of efforts to achieve improvements in data quality. This is strongly advised in light of our analysis of complexity versus data quality. There are a number of data collection efforts under way within EIA, and OTI should consider making use of these resources. The second strategy we recommend is that new modelling endeavors should be structured along the lines outlined by Ed Quade in his presentation, i.e., a family of small, simple models, each addressing one aspect of the problem, which can be used to form

an impacts matrix, with alternative policies on one axis and impacted areas (air quality, water quality, socioeconomic impacts, etc.) on the other. Simple models are easier to understand, quicker and cheaper to run, easier to develop and validate, and their uncertainties are easier to quantify. Simpler models also have less institutional momentum. They are thus far less likely to be applied (or inappropriately modified to apply) in areas to which they are essentially blind. The comprehensively large, highly competitive models are not justified by the data inaccuracies which are inherent in a field as uncertain as energy and environmental planning.

- o OTI and EIA should sponsor an Energy Statistics Committee at the National Academy of Sciences or other independent body for continuing research, assessment and evaluation, and consulting on the development of energy statistical programs.

At present, there is no independent body that oversees the collection, compilation and use of energy data. EIA has a group that does model validation in addition to the groups that do validation of energy information. There is also an ad hoc committee sponsored by the American Statistical Association which advises EIA on the use of models and survey methods. OTI's policy analysis models, however, are not reviewed for the consistency and accuracy of the data used, which contributes to a lack of confidence in their results by the modelling community, the policy analysts, and the public in general.

The working group recommends that OTI and EIA sponsor the formation of an Energy Statistics Committee at the National Academy of Sciences (NAS), the American Statistical Association, or other suitable organization for the purpose of continuing research, assessment and evaluation, and consultation on the development of energy statistical programs. This permanent committee would continue the efforts begun by the NAS ad hoc Committee on Energy Consumption Data and other groups and would provide an organizational means for review and evaluation of current and proposed programs. This committee should consist not only of statisticians and others familiar with data collection techniques, but also of modellers and other users of energy data. Having such an independent overview group will induce more confidence in the data going into models and the results coming out.

- o Independent model and data validation and verification must be emphasized if energy-environmental policy research and analyses are to be credible to peers, policy analysts, and those affected by model-based policy decisions.

Modelling for energy and environmental policy analysis has not yet reached the stage where it can be considered a discipline. Models, the data used by them, and their results are not usually described in the open literature in enough detail to assess their validity.

The working group recommends validating all models used in support of policy research. The goal of validation is to give both the modellers and the users information about how they can be used most effectively and how much confidence can be put in the results.

Validation of models used for prediction should include a test forecast of data that is known but not used in estimating the model. The test forecast should be performed using both estimated and actual values of exogenous inputs to distinguish errors due to difficulty in predicting the values of these inputs from errors due to model specification.

A second form of validity test should examine the model's structure to ascertain whether the model's behavior is consistent with the theoretical beliefs of its developers. A third form of validation examines the content of the model to check whether it contains the features necessary for the type of analysis for which it was intended. These types of validations check for the possibility of nonsense results and determine which issues the model can or cannot be used to examine.

EPRI has initiated two mechanisms for model validation, the Energy Modelling Forum and MIT's Model Assessment Laboratory. In the Energy Modelling Forum, different models are run over the same scenarios to provide a basis for discussion and comparison. Not only is this activity very helpful to the modelers, but participation increases the model's exposure and can increase its credibility. In the Model

Assessment Laboratory, models are examined independently, but with the cooperation of the model developers. OTI should take advantage of these approaches to model validation.

The working group notes that validation, participation in energy modelling forms, independent model assessment, and sound model development practice all require good model documentation.

Summary

The working group on measurement issues examined the relationships between the data and the economic-energy-environmental models that are used for policy analysis. Since policy decisions can have their most critical impacts on a small part of the country or a single economic sector, it is often necessary to model impacts at this level. The quantity and quality of the available data, however, severely restrict the comprehensiveness of such a model. For use in a model, demographic, economic, energy, and environmental data must be compiled on a consistent basis. Furthermore, survey data must be supplemented by statistical sampling to acquire the specific information needed for in-depth impact studies. OTI can play a major role in ensuring that the data it needs for policy analysis models are collected and compiled in a suitable way by establishing a formal interface between the modellers and the statistical agencies which collect the data.

A second consideration of the working group was improving the use of data so that the results of models could be made more credible. Although it is generally realized that uncertainties in the data lead to uncertainties in the results, they are usually not quantified in presenting the results to the policy analyst. Moreover, given the quality of the data, there is a point at which making the model more complex will give less accurate results. These considerations must be kept in mind when formulating policy models. The working group noted that the credibility of results would be enhanced if an independent group were to oversee energy data collection and if both models and data were independently validated.

WORKING GROUP REPORT (3):
USE OF MODELS FOR POLICY ANALYSIS

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Introduction

The framework within which a model or family of models is applied, and the relationship of this framework to the decisionmaking process, are major determinants of the successful use of a model for policy analysis. The charter of the working group was to review the application of models for environmental policy analysts and recommend improvements for use of these numerical models. The group focused on the question: "How should models be used for OTI environmental policy analysis?" It should be noted that this framework excluded discussion of the structure of, or linkages between, the models being used and of the sources, availability and quality of the data supporting those models. These latter topics were to be addressed by the other working groups. Detailed information on EV and OTI operating policies and structure were not available for review during the working group meeting. Therefore, the recommendations listed below do not always imply a corresponding known deficiency in OTI policies.

Recommendations

The discussion of specific recommendations centered on three topic areas. These were: regional involvement in the assessment process, design of the assessment programs, and the relationship between the modeller and the user (decisionmaker). Of these, the first (increase regional involvement in assessments) was felt to be by far the most important. The following paragraphs present the discussions and recommendations of the working group in each of these areas.

Regional Involvement in Assessment Process

Increase Regional Detail and Involvement in Model Assessments

It was agreed by the working group participants that by far the most important recommendation which could be made to improve the accuracy, acceptability, and credibility of OTI model assessments was to substantially increase regional involvement in the assessment process. The specific recommendations listed below represent a series of implementation strategies for this general principle. It was further agreed that the state should be the basic sub-Federal unit, or region, for implementing this involvement. The state was selected as the basic unit since it was felt that implementation of Federal energy

policy will be dependent upon state concurrence and support. More specifically, OTI assessments will benefit because:

- (1) The basic sub-Federal political boundary is the state. States have appropriate institutions with regulatory and planning responsibility (e.g., Energy Departments and Public Utility Commissions);
- (2) Many decisions critical to energy futures are made at the state level (e.g., power plant siting);
- (3) The states can define and enact energy policies of their own; and
- (4) The states can act as a focal point for the collection, dissemination and analysis of local energy, demographic and environmental data.

The discussion on sub-Federal units was directed toward identifying actors and institutions which should be considered. It was unanimously agreed that the computational assessment of pollutant transport and impacts may be appropriately conducted at other geographic scales. Long range SO₂ impacts, for example, may be analyzed at a regional level, while data input, state and local policies and impact interpretation could be provided by actors from each state within the region.

This set of recommendations represents the working group's effort to directly address top-down/bottom-up integration. It was felt that an appropriate integrating principle is the coupled concept of constraints and goals. Federal policies, goals and energy disaggregations (pie splitting) constrain state options. State policies, actions and goals restrict the opportunities available to DOE to fulfill Federal scenario goals. Thus, the design and operation of a modelling system should allow (as a minimum) for both the transmission of, and consideration of goals and constraints between state and Federal levels. The resulting format can serve as a basis for interactive communication between Federal and state actors. Consistent with the concept of constraints is a hierarchical system of environmental impact assessment. Detailed analyses could be conducted by a regional entity (as is done by the national laboratories) based on "control totals" obtained from a DOE national assessment.

Two pathways were identified for infusing regional involvement into the OTI environmental assessments. The first of these is pre-assessment data inputs. State, local and private sector energy development plans, energy siting policies, and energy goals can both direct and constrain the implementation of Federal initiatives. These data are now compiled at the state level and can be incorporated into OTI data bases as bottom-up constraints for industry, end use fuel, and utility disaggregation into regional, state and sub-state areas. The second pathway is the development of an interactive hierarchical system for the cooperative conduct of the environmental assessment of an energy policy. In general, the use of the second pathway was recommended only for long period assessment and not for the quick turn-around studies (e.g., 1 to 2 week study duration). The first pathway is applicable for studies allotted either amount of time. The following specific recommendations are provided for the enactment of improved regional involvement in OTI assessments.

o Incorporate State-Level Inputs into OTI Siting and Disaggregation Systems

Existing data bases (e.g., SEAS) used for disaggregation or siting energy and industrial activities should include detailed input from state levels. This input should include state and local siting and fuel mix priorities, state energy development plans, goals and constraints, or regulations which could influence the future distribution of energy use. Individual states would be responsible for development and periodic update of this input either directly to OTI or through appropriate national laboratories. Format and spatial level of detail (state, AQCR, ASA, county, etc.) would be specified by OTI to insure compatibility with existing data bases and disaggregation schemes. The purpose of this expanded state detail data base is to modify Federal energy disaggregations in order to reflect state and regional trends and policies, and identify possible impacts of state level policies on Federal scenario options. Implementation mechanisms for this

recommendation include: data base modification, determination of state level points of contact, establishment of a data transmission and review process, and establishment of a data update and modification mechanism.

o Develop a Common Energy Accounting System

Establish, in cooperation with state agencies, a common structure for describing and accounting for energy flows in each regional or state energy system, including fairly detailed demographic and end use descriptors. The adoption of such a system by all state level participants would substantially enhance the feasibility of the previous recommendation, and will establish a certain measure of consistency for interactive participation between state and Federal levels for the conduct of environmental assessments of alternate energy policies. An inherent element of this recommendation is the development at the state level of a common historical set of energy data.

o Develop a Taxonomy of Environmental Impacts

Some environmental analyses are properly addressed as spatial aggregates at a national level while others are best addressed at a multi-state regional level (e.g., acid rain or SO₂ in the Northeast). Similarly, some studies require long-term assessments (e.g., life cycle analyses) while others can address only a single year (e.g., impact of a revised environmental residual emission regulation on energy development). To the knowledge of the working group, the relationship between the nature of an environmental impact and the scales (spatial and temporal) for its assessment has not been made explicit. It is, therefore, recommended that a taxonomy of environmental impacts and the spatial and temporal scales best suited for their assessments be constructed. The adaptation of such a system would then direct the specific types of models and level of their application to respond to a policy related question. Some discussion was directed toward completion of such a matrix. However, time constraints of the workshop prevented substantive development. It is recommended that OTI undertake a cooperative program with regional representatives for the development of a taxonomic matrix and for its integration into the assessment process.

o Establish a Hierarchical Assessment Methodology

This recommendation involves both structural and procedural components. Consistent with the impacts taxonomy OTI would directly calculate (using SEAS or other appropriate models) only those impacts best addressed at a national level. Resulting siting patterns and total activity levels would be used by regional laboratory and/or the individual states as drivers and as control totals for the socioeconomic and environmental impact assessment at the state or other level. Models to be used in this second portion of the hierarchy would concentrate on spatial distribution and ambient quality (bottom-up) models. Interface between the two levels of the hierarchy would be provided by the national and regional outputs and by state level inputs to the siting process. Inherent elements of this recommendation are that OTI undertake a coordinated program with regional and state personnel to develop consistent, compatible state and sub-state energy-environmental models, and that the assessment process represent an interactive iterative process. It is envisioned that this hierarchical approach would apply only for long-term assessment programs.

Design of Assessment Program

Environmental assessments conducted by OTI are now constrained to use only scenarios (national energy supply and economic scenarios) supplied by others. Current scenarios are designed to examine the effects of perturbations in GNP, world oil prices, population level and the like. While the resulting

environmental assessments are useful, their true significance cannot be determined until the plausible range of energy-related environmental impacts has been determined. Such determination is dependent upon the generation and evaluation of scenarios specifically designed to explore variations in environmentally important parameters. What energy supply mix for the year 2000 generates the least environmental damage? Which mix generates the greatest environmental insult? What is the likelihood that either will be approached? What is the dollar and/or environmental cost of marginal changes in the future energy mix of a given scenario? Addressing questions such as these will provide a framework within which to evaluate the relative significance of the environmental implications of any specific scenario. Two specific recommendations were made. These are:

- o Develop Environmentally Significant Energy and Economic Scenarios

Assessment of the environmental impacts of an energy policy requires the analysis of several scenarios based on that policy which were specifically constrained to address the range of resulting possible environmental impacts. As a first step it is recommended that the development of environmentally significant alternative energy and economic scenarios be pursued. This will require that assumptions and goals are identified and incorporated into the scenario structure before PIES or other models are used to generate economic and total energy demand forecasts. Only in this manner can the environmental assessments conducted within OTI be consistent with basic scenario assumptions.

- o Estimate the Energy Cost of Environmental Standards

Techniques and measures are available (e.g., shadow prices) to estimate total and marginal costs of environmental standards and policies. These functions, placed in terms of energy cost, will provide a rational basis for the evaluation of beneficial changes in either present or proposed standards. It is therefore recommended that OTI initiate a program to estimate explicitly the energy cost of environmental policies and that the resulting cost figures be incorporated into the DOE decisionmaking process.

Assessments were divided into long-term assessment and short-term assessments. It is recommended that, rather than separate these categories along fixed time spans (e.g., short-term is less than 5 years), short-term and long-term assessments should be differentiated by the nature of the environmental questions being addressed. With this type of differentiation, the identification, the need for a short or long time frame study will also identify the types of models needed and the spatial levels at which they should be applied. It is suggested that:

- o Short-Term Studies Be Used to Address Specific Tactical Questions

Generally, short-term assessments are suited for emission related questions rather than environmental impact or ambient quality questions. The question, "What is the effect of delaying new auto emission standards for two years?" can adequately be addressed at the level of increased residuals over a fixed time period (two years). Ecosystem and ambient quality impacts need not necessarily be addressed. Similarly, short-term assessments are suited for standards compliance issues (where the question at hand is how existing energy-related emissions compare to some standard), and to operational questions as opposed to those involving major capital investments. Short-term studies are appropriate for high spatial aggregation (Federal region or nation), are often "quick response" studies, and should be evaluated in a top-down assessment mode. They are normally addressed in terms of residuals, and not the impacts of those residuals, and do not tend to require detailed regional or state input or interaction (bottom-up input).

- o Long-Term Assessments: Impact Assessment Period Should Cover Entire Period of Duration of Impact

The assessment period appropriate for consideration in a long-term environmental assessment should be based on the full life cycle of a major energy facility (often the time to 50 years), the Research Development, Demonstration and Commercialization for emerging technologies included

in a scenario, and the duration of the environmental impact (the direct impact plus system recovery time). Thus, major impacts on a forest ecosystem may require consideration of a hundred-year time frame in order to capture the full impact being assessed. The environmental modelling techniques used for long-term studies must be oriented toward the receptor systems (ambient quality modelling, human health or populations at risk modelling, and spatial and temporal distribution of residuals assessments) rather than toward source systems (e.g., emissions studies). These techniques are "bottom-up" modelling approaches which should be applied at regional, state and sub-state levels and will thus require coordinated analysis throughout the country. Therefore, long time frame studies require longer study times, will involve some iterative interaction between Federal and state or regional representatives, will tend to be strategic rather than tactical, and will focus on the environmental/health impacts of the residuals rather than emission rates themselves.

It is recognized that impact forecasts over a 50-year time frame are subject to increasing uncertainty due to the implicit assumptions concerning major institutions, their behavior, general societal behavior, and a wide range of other surprises. Thus, the concept of uncertainty as it is applied for long-term assessments is far more important than for short-term assessments.

Relationship of Modeller and User

Models and model output are often found irrelevant to the ultimate decisionmaking process. To the extent that the application of models for environmental assessments is at the discretion of OTI, it is important that OTI design model use so as to increase their utility, attractiveness, and relevance to policy decisionmakers. Four specific recommendations were identified in this area.

o Use of Publicly Recognizable Units

Solicited inputs and model outputs should be converted into units pertinent to public decision-making. For example, tons of SO₂ per state per unit may not be meaningful to decisionmakers. Emission data should be converted to populations at risk or to other human health related indicators. Where these conversions cannot be readily made, it is recommended that future investment in model design be redirected away from expanding the capacity, scope or quality of the model calculations toward a revision in model operation, data input, and computation. This change will increase compatibility between model output form and that desired for decisionmaking.

o Incorporate Uncertainty into Model Operation and Present Uncertainty Measures with Model Results

All major economic/environment models incorporate some degree of uncertainty. Models can be made normative in order to remove some sources of uncertainty from influencing the analysis. Further, the use of a scenario approach substantially reduces the uncertainty associated with model calculation if the scenario is put in the form: "If population, GNP, oil prices, etc., are as forecasted by the scenario, then the following environmental impacts will result." However, uncertainty in model results still exist. It is recommended that this uncertainty be recognized, and that its sources be identified (e.g., scenario, data base, model linkages, etc.) and incorporated into model output. A result numerically forecasting a seven percent reduction in NO_x for the year 2000 does not, in fact, forecast exactly within a range between two unknown limits with seven percent as a most likely value. A pertinent statistical question is whether the seven percent result is significantly different from zero. Yet current model output cannot provide this information. Such an analysis requires the statistical incorporation of uncertainty (data and computational relationships) into the model calculations. In fact, incorporation of uncertainty into model results is a critical step in increasing the real value of the model for decisionmaking.

There were more specific recommendations made. The first of these is that the presentation of a single point value in model output be replaced by a range of probable values with a listing of the factors which generated the uncertainty and an estimate of the time and effort required to improve the estimate. The second of these recommendations is to publish a comprehensive list of model and data base assumptions and to encourage open review of these assumptions and their associated uncertainty.

o Foster Decisionmakers' Confidence in Model Results

This is at best a nebulous factor to address, and intuitively, requires long-term successful exposure of the decisionmaker to economic and environmental models. However, three specific recommendations were made which will tend to increase decisionmaker trust in OTI model results.

- (1) Increase the availability and detail of documentation on OTI model systems.
- (2) Encourage and support scientific, Congressional staff and decisionmaker critical review of SEAS operation, structure, assumptions and supporting data bases. This should include publishing details of the model in the open literature.
- (3) Reduce complex model elements to a series of coupled small single purpose models which can easily be substantiated or verified.

o Design the Form of Output to Match Decisionmaking Needs

Model output currently is provided in extensive tabular form. The use of this output would be greatly enhanced if: (1) output is interpreted and converted into essential information prior to release; (2) output can be disaggregated over a variety of sub-groups (e.g., income, age, spatial location, etc.) as best suits the needs of a specific analysis; and (3) emphasis is placed on condensation of information into as compact a form as possible without sacrificing meaning or clarity. Graphical and mapping displays are ideally suited for this purpose and are recommended for increased use in OTI assessments.

It was felt by the workshop participants that the modeller poses a moral obligation to take such steps as are feasible to minimize the opportunity for misuse of model results. Several specific recommendations were made to this end. These are:

o Decrease the Separation Between Modeller and Decisionmaker

In order to decrease the misuse and misinterpretation of model results, it is desirable to decrease the separation between the modeller and the decisionmaker (ultimate user). This can be accomplished by removing the institutional layers (buffers) between user and modeller; by promoting an ongoing dialogue between user and modeller; by using this dialogue to impress upon the user the strength and frailties of the model(s); and by insisting upon professional integrity in the interpretation and application of model results.

o Design Format of Results to Minimize Misuse

A large part of model misuse stems from improper interpretation of model output. Assumptions, limitations, approximations in linkages and methodologies, and input data inaccuracies are often forgotten in the face of a precise numerical output. However, that output contains real information only in light of all of the assumptions and uncertainties inherent in its calculation. It is therefore recommended that, as a minimum, the following steps are undertaken by the modeller. Model output should be interpreted and converted into relevant information before release. Released information should be tailored to the needs of the user for each specific model application. Detailed model documentation should be prepared and distributed to potential users.

o Small, Simple Models Discourage Misuse

Model structure and complexity significantly affects the tendency to misuse model results. Small, simple, single purpose models discourage misuse while large multi-objective complex models present an unending opportunity for misuse and misinterpretation. It is recommended that OTI emphasize the use of small, simple models linked to perform required computations and that these linked models be operated in a hierarchical system.

Summary

Working group discussion centered on three general areas. The most important of these areas was regional involvement in the assessment process. The group concluded that states are the best level for obtaining this direct regional involvement. State involvement should include both the input of state goals and policies into initial siting and disaggregation processes and an involvement in the impact interpretation and evaluation procedures. The second general area was the design of assessment programs. Two sub-areas were identified and discussed: analysis of environmentally designed scenarios, and identification of the appropriate timeframe for policy analysis studies. Specific recommendations were made in each of these areas. The final general area addressed by the group was the relationship between the user (decisionmaker) and the model, or modeller. Included were discussions and recommendations for making models and their outputs more attractive to decisionmakers and for guarding against misuse of model results by these policy analysts.

TABLE 1
SUMMARY OF WORKSHOP RECOMMENDATIONS

MODEL STRUCTURE

Long-Term Recommendations:

- Develop a core set of related models that are modular, dynamic and consistent.
- Form an advisory group to establish the appropriate methodological framework of models.
- Establish a model system with an inter-industry accounting framework and interregional linkages among the different sectors of the economy and environment.
- Require adequate up-to-date documentation.

Short-Term Recommendations:

- Improve base year data (national and regional) of the current OTI models.
- Improve accounting framework (energy/economic) of the current OTI models.

MEASUREMENT ISSUES AND APPROACHES

Data System and Source Recommendations:

- Develop and maintain an integrated system of socioeconomic, energy and environmental.
- Interact more effectively with EIA and other statistical agencies that collect data.
- Acquire detailed environmental and technology characterization data.
- Include statistical estimates of the uncertainties in data as input and as model output.

Procedural Recommendations:

- Develop simpler models congruent with real measurements and not "synthetic" data.
- Sponsor an Energy Statistics Committee at the National Academy of Sciences.
- Emphasize independent model and data validation and verification.

Table 1 (continued)

USE OF MODELS FOR POLICY ANALYSIS

Regional Involvement in Assessment Process:

Incorporate state-level inputs into OTI siting and disaggregation systems.

Develop, in cooperation with state agencies, a common energy accounting system.

Establish a hierarchical assessment methodology.

Develop a taxonomy of environmental impacts and the spatial and temporal scales best suited for their assessment.

Design of Assessment Programs:

Develop environmentally significant alternative energy and economic scenarios.

Estimate the total and marginal costs of environmental standards and policies.

Use short-term studies to address specific tactical questions (e.g., standards compliance).

Base long-term assessments on the full cycle of a major energy facility.

Relationship Between Modeller and User:

Convert inputs and model outputs into units pertinent to decisionmaking.

Incorporate uncertainty into model operation and present the levels uncertainty with model results.

Foster decisionmakers' confidence in model results by increasing availability and documentation on OTI model systems.

Design the form of output to match decisionmaking needs.

Decrease the separation between the modeller and the decisionmaker.

Design format of model results to minimize their misuse.

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APPENDIX I

Essay on Data Quality, Model Complexity and Uncertainty

David Leinweber
The RAND Corporation

"It's very difficult to predict, especially the future." -- Neils Bohr

Building and using a model entails a set of related activities. Input data must be collected, the model itself needs to be precisely specified and constructed, as well as a method interpreting the results. In engineering and the "hard" sciences this process can be fairly straightforward, but when the domain of the model is sociopolitical or economic or both, it is considerably more difficult.

The Data

The input information available to economic and policy modellers is not of a uniformly high quality. In 1950, Oskar Morgenstern discussed these problems in On the Accuracy of Economic Observations. He cited multiple sources of error, including the lack of designed experiments, deliberate hiding of information and lying, improperly trained observers, poorly designed questionnaires, lack of proper information definitions, measurement errors, and the inability to allow for unique or changing circumstances.

Things are not much better today. There is an unreported portion of the GNP that may amount to more than \$200 billion. This represents activity in the barter economy, off-the-books employment, drug traffic (which recently surpassed tourism as the largest industry in Florida), and other unsavory endeavors. Since \$200 billion is 10 percent of the total reported GNP, it seems fair to assume that the accuracy of much of the published information on inter-sector transfers and the like may be suffering as a consequence.

There are still ample reasons for deliberate data distortions. A notable example is DOE's multiple tier oil pricing system, which turns into cash for what is apparently a disturbingly large group of petroleum dealers.

Bureaucratic and institutional inertia often encourage shortcuts in meeting Federal reporting requirements. It is much easier to use or adjust last year's numbers than to bother with actually going out and measuring what is supposed to be measured.

The list of possible problems with economic information is endless. Let it suffice to say that economics is not physics and never will be.

The Model

So we have all this rotten data. What does this imply about model design? The answer is found in Figure 1, which shows a series of graphs of model error versus model complexity. Figure 1a shows one kind of model error (the error of specification). This is the error in the model's prediction if it were working with perfectly accurate ideal data for inputs. The only legitimate reason for making a model more complex is to increase its accuracy. Complicating a model without an increase in accuracy is, in game-theoretic terms, an inadmissible strategy. This doesn't mean it doesn't happen, only that

in an ideal world, it wouldn't. The downward curve of e_s , the error of model specification, reflects this idealized notion. Real models may be worse, but not better.

The second curve, in Figure 1b, shows e_m , (the compounded error of measurement) in a model. This is the error that arises from the unavoidable errors in real data that compound as more arithmetic operations are performed on them. As the models grow larger and more complex, the compounded error in the prediction increases.

Adding the two curves shown in Figures 1a and 1b produces the curve of total error, e_t , shown in Figure 1c. The important point is that this curve has a minimum. There is an optimal model complexity for attacking a problem based on real, i.e., imprecise data. Further complicating the model buys nothing. It does impose an additional cost in accuracy of predictions, as well as the cost of resources required for a more complex analysis.

An important point is made by considering what happens when the quality of the data gets worse. Figure 2a shows e_{m2} , the compounded error of measurement curve for a set of data worse in quality than was used in Figure 1. The original data from Figure 1 is shown on the same axes as e_{m1} .

Adding both e_{m2} and e_{m1} to e_s , the error of specification, produces two total error curves, e_{t1} , identical to that shown in Figure 1c, and e_{t2} , the total error for the poor data case. Notice that the minimum point on the curve moves to the left. As the data gets worse in quality, the optimal level of model complexity decreases. Put more succinctly: Lousy data implies simpler models.

When this notion is taken to the limit, with the quality of the data becoming increasingly poor, the optimal complexity for the model using that data (denoted by C_2 in Figure 2b) approaches zero. A model of zero complexity is an intuitive guess. When the data are non-existent or worthless, this is the best model available.

There is good evidence that many real models are more complex than they should be, given the quality of the data they run on. Much of the detail in models is based on presumed detail in the data which, on closer inspection, is not really there. An overly detailed and complex model may be well past the point of diminishing information returns with regard to the domain under investigation.

The Application

It should go without saying that a model should be appropriate to its application. For new models, this should be fairly well assured; for existing models, it is not so certain. (There is a great temptation to apply models in areas beyond their intended range, to ask questions about issues to which the model is essentially blind.) The situation is worst in the case of large, expensive, complex models that represent a substantial investment by the sponsors. This kind of institutional momentum leads to the development of a myriad of add-on modules, adjustment factors, complex feedback systems and other contrivances which add little or no value to the information derived from the model. This situation is the logically inadmissible strategy referred to previously, in which the complexity of the model increases without a reduction in the error of specification.

The Results

What happens after the data has been collected and the model designed, implemented, and applied to the problem? The issue becomes one of deciding on how to interpret the results.

The model's predictions are in the form of numbers, which, hopefully, in some way describe what the future will be. Placing a lot of credence in the absolute level of the prediction, the value itself, can be a risky proposition, especially for times more than five or ten years into the future. The Energy Modelling Forum at Stanford University applied a group of coal models to a standardized problem

and came up with a remarkably broad set of predictions. The curves from the different models tended to move together, but the absolute values of the predictions varied widely (see Figure 3). The implication is that it may be better to interpret the results of modelling analyses in a differential mode; i.e., to look at the change in the predictions for one case relative to another. In policy analysis, this is often the kind of question one is interested in anyway. If there are two or more alternative actions under consideration, the basis for a differential comparison clearly already exists. For most problems, a base case or business-as-usual scenario can be constructed to provide a reference point for the differential comparisons. The use of this technique is shown in Figure 4, a map showing estimated 1985 sulfur oxide emissions under the original Carter energy plan relative to estimated emissions if the plan were not in effect.

Differential mode interpretation is probably the safest way of looking at model results in use today, but there is still room for improvement. There are uncertainties and errors in the model's results, as well as in its inputs. They are somewhat more difficult to quantify, since it is a fairly intractable mathematical procedure to trace changes in the distribution of the input variables as they churn through any (but the simplest) model and become output variables. If this could be done, one could then interpret the results in a differential probabilistic sense, and obtain measures of the statistical validity of one's results, along with the results themselves. Generating and convolving the distributions of predictions or approximations of these distributions allows the modeller to distinguish between a real statistically significant effect and one that is just random noise.

The map in Figure 4 corresponds (partially) to the request: "Show me those regions which will experience an increase greater than 10 percent in sulfur oxide emissions." A probabilistic differential map would correspond to requests similar to: "Show those regions which will experience an increase greater than 10 percent in sulfur oxide emissions, with a statistical likelihood of at least 80 percent." For a complex model, it is essentially impossible to do this precisely, but it can be done in an approximate way. If reasonable assumptions are made concerning the accuracy of components of the model's final results or if actual data on the accuracy of some components are known, it is usually possible to envision a practical way to combine the known and assumed uncertainties to produce some kind of approximation to the distribution of predictions, and to convolve these distributions, yielding an approximate probabilistic differential result. Some of this must be done on an ad hoc basis; it may be best to use a range of assumptions concerning the uncertainties in the models, ranging from very optimistic to very pessimistic, and see how this affects the confidence intervals for the results. If you have to make heroic assumptions everywhere before anything significant beyond the 10 percent level appears, it is likely that your model is not really telling you very much. If 70 percent likelihoods are seen in the results with moderate assumptions you may well be observing a real effect.

Important policy decisions should not be based on noise. While it is far from clear that such decisions actually are closely coupled to modelling, it is worthwhile to make some attempt to determine the validity of one's conclusions, whatever their ultimate application may be.

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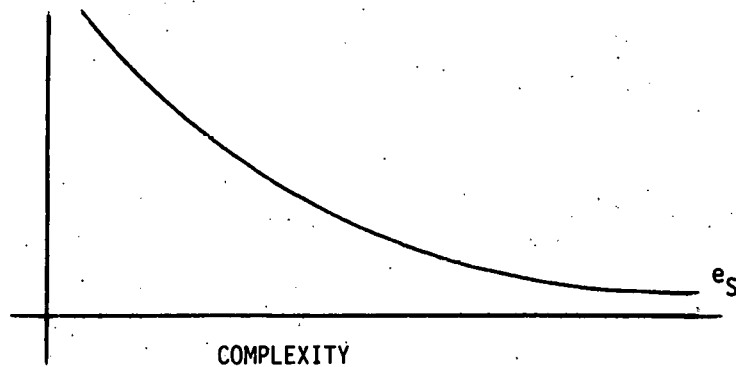


Figure 1a.
Error or
Specification

ERROR

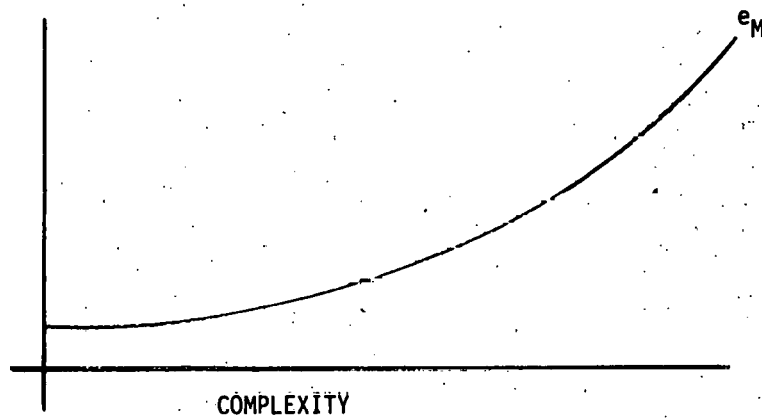


Figure 1b.
Compounded Error
of Measurement

ERROR

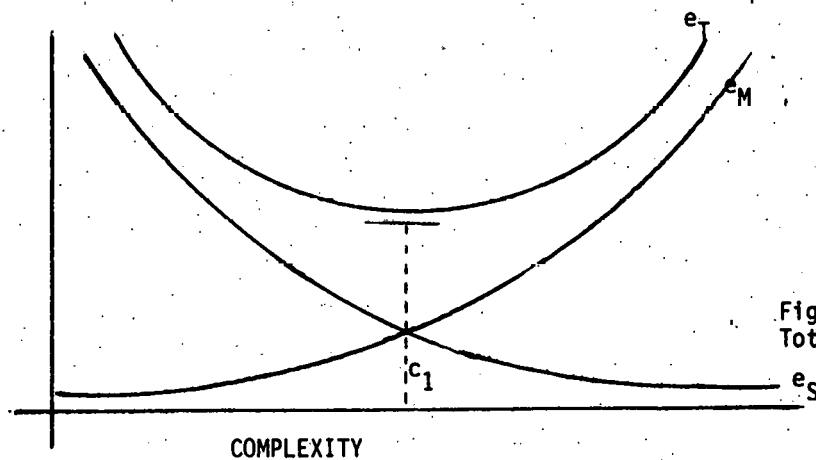


Figure 1c.
Total Error

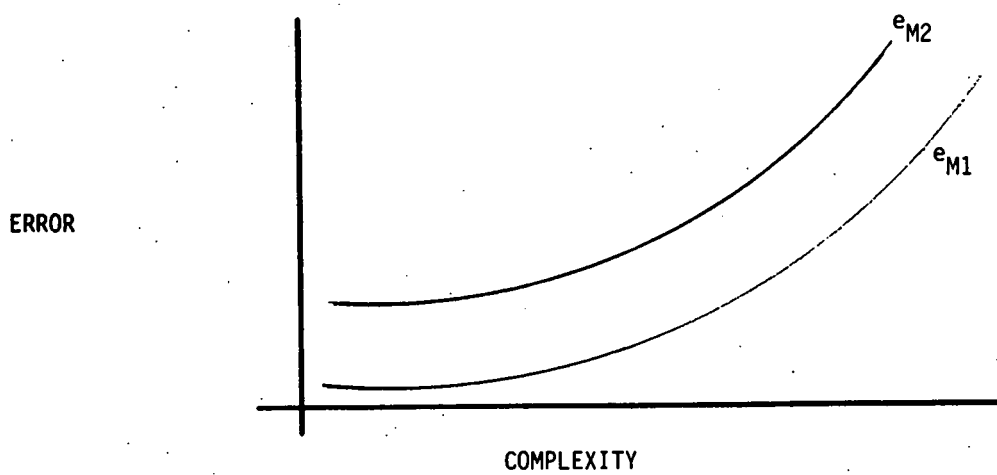


Figure 2a.
Compounded Errors
of Measurement

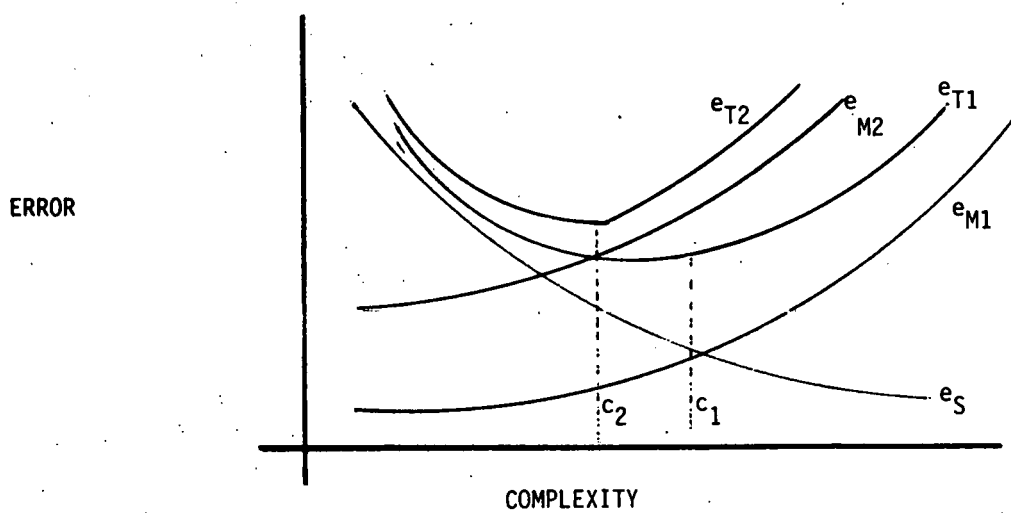


Figure 2b.
Total Errors

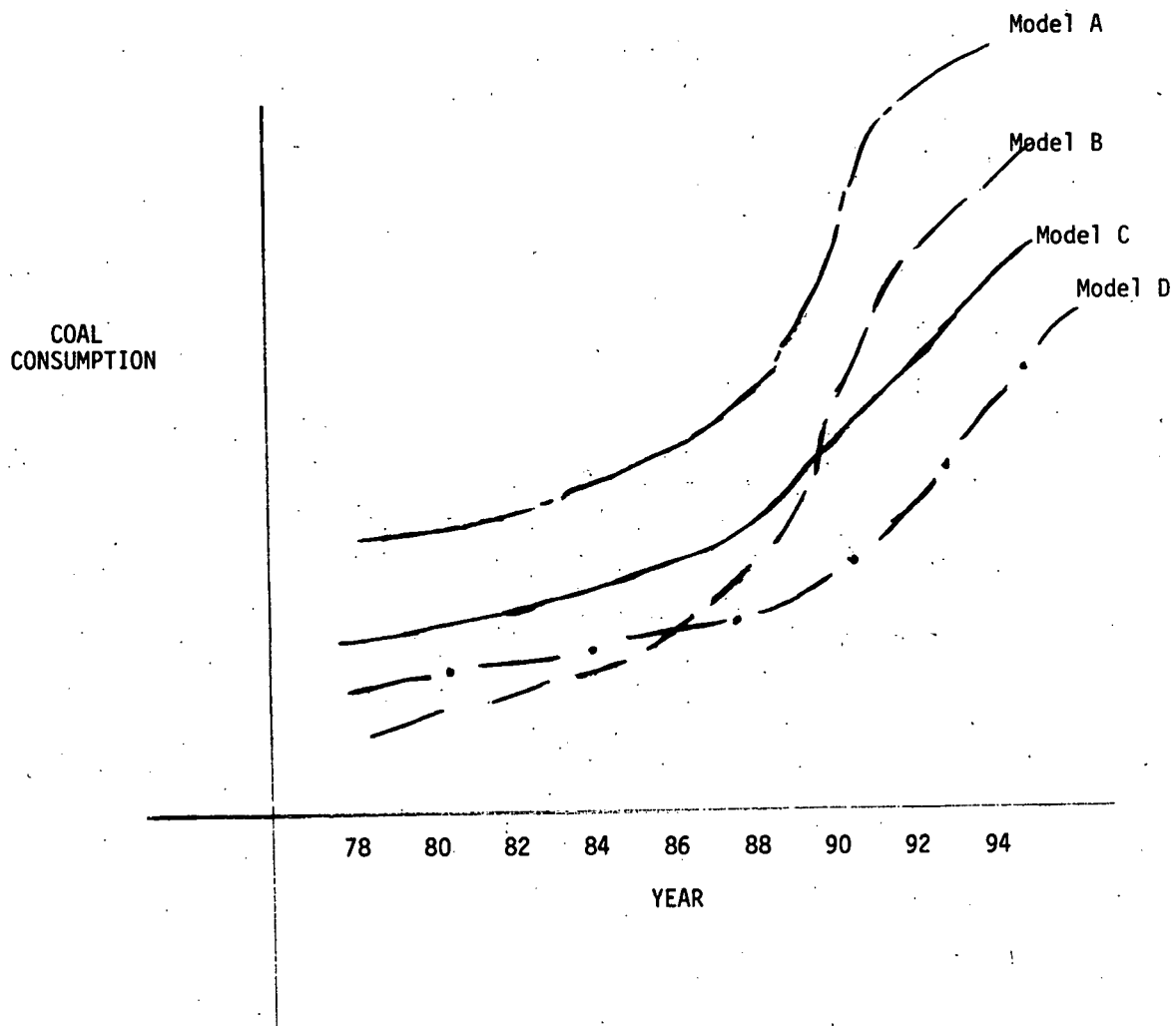


Figure 3. Results of Study Comparing Coal Models Using Identical Inputs

APPENDIX D

PROCEEDINGS OF A WORKSHOP ON GROUND WATER AND ENERGY

Albuquerque, New Mexico

January 29-31, 1980

Harbridge House, Inc.
Under Contract to
Los Alamos Scientific Laboratory

May 1980

Sponsored by
Assistant Secretary for Environment
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CONTENTS

	<u>Page</u>
Preface	D-ii
Introduction	D-1
OTI's Mission	D-1
The Workshop	D-1
The Report	D-2
Key Findings	D-3
What is the Nation's Ground Water Stock? (The Supply Issue)	D-7
What are the Barriers to Use of Ground Water Resources for Energy Production? (The Conflicts and Barriers Issue)	D-11
What are the Options Open for Use of Ground Water for Energy Production? (The Alternatives)	D-15
Workshop Participants	D-20
Appendix I: Core Issues Listing	D-21

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the 1990s, the number of people in the world who are illiterate has increased from 1.2 billion to 1.5 billion. The number of illiterate people in the world is projected to reach 1.7 billion by the year 2015. The number of illiterate people in the world is projected to reach 1.7 billion by the year 2015.

INTRODUCTION

There can be no doubt that energy production will be one of the foremost concerns of the 1980s. Large quantities of water are forecast to be required for this production. Surface water supplies, however, will not be able to meet the demand in all locations, and energy producers will turn to other sources, including ground water.

The U.S. Water Resources Council's Second National Water Assessment recently identified inadequate surface water supplies in 17 of the 106 water resources subregions of the nation. Serious ground water overdrafts occur in eight of these, and moderate overdrafts occur in 30 additional subregions. Most subregions that suffer from surface water supply problems also experience ground water supply problems.

The Second National Water Assessment concluded that water supplies are generally sufficient to meet water needs for all beneficial purposes. However, in some regions energy development will intensify competition for available water supplies. The use of ground water and other more expensive alternatives to surface water may ease the disruptive aspects of energy development.

OTI's Mission

In view of complex environmental/energy decisions, the Environmental Impacts Division of the Office of Technology Impacts develops analytical methods for conducting policy analyses supporting decision making. The methods development process often begins with a workshop of leading experts and specialists in the relevant disciplines and issue areas; workshop findings are subsequently utilized by OTI to form a more solid foundation for viable policies.

The Workshop

The National Workshop on Ground Water and Energy Production was envisioned as a tool through which OTI could obtain insights, information, and methods (on environmental, economical, physical, political, legal, and social issues) to use in its analyses, models, and assessments.

To accomplish this, the Workshop comprised both plenary sessions and individual working groups. The former provided opportunities for all participants to explore issues from a broad perspective, whereas the latter enabled participants to focus on the three following areas:

- Ground water supply.
- Conflicts and barriers to its use.
- Alternatives or solutions to the various issues.

Each working group (supply, conflicts and barriers, and alternatives) was composed of approximately 20 invited participants, chosen for their expertise and special knowledge of that topic. In addition to their professional experience, the participants represented diverse geographic and occupational backgrounds. Representatives of DOE and other Federal agencies provided the perspective of the Federal Government.

A list of participants is provided in Appendix A.

The Report

This report summarizes information and insights gained by the Office of Technology Impacts during the course of the Workshop. The Key Findings section summarizes the most important facts discovered during the Workshop. The three general topics that follow (Supply, Conflicts and Barriers, and Alternatives) are those described in the Core Issues statements (see Appendix B). The statements are reflective of the recommendations and analyses prepared by the several working groups.

A supplementary volume to this report will contain Workshop proceedings, and will include the draft plenary presentations and the reports of the three working groups.

KEY FINDINGS

General water supplies are adequate for energy needs nationally, but local shortages exist.

- Water supplies are not a limiting factor in overall United States energy development at this time.
- The nation's ground water supply consists of approximately 200 billion acre-feet located within a few thousand feet of the land surface. A comparatively small proportion of this amount is withdrawn each year (fresh water withdrawals in 1975 amounted to 92 million acre-feet), a portion of which is replenished. Some areas, though, either have no ground water supplies, or are "mining" the resource.
- A nationwide abundance of water does not lessen the problem of localized shortages; localized shortages of surface water, however, do not necessarily indicate a shortage of ground water.
- Ground water "availability" involves two factors: the physical/technical ability to withdraw water from an aquifer; and community acceptance of this withdrawal.

Data bases and modeling tools are generally well developed at the regional level, but data are often deficient at the local level.

- Information on ground water resources is much more complete for use in assessments on a national or regional scale than for effective use in many extremely localized studies.
- In some regions the data base on replenishable (surface and ground) water supply is quite strong, since existing gauging stations often measure ground water discharge to streams, as well as surface runoff. However, where there is no dynamic linkage between aquifer and gauged stream, there is a potential weakness in the data base regarding that aquifer.
- For Department of Energy analytical purposes, better methods of integrating, sharing, analyzing, and displaying ground water information are needed.
- The development of a hydrogeologic characterization of all major aquifers within each region through U.S. Geological Survey Regional Aquifer System Analysis (RASA) will improve assessment and planning capabilities.

- Management, planning, and assessment activities can be greatly aided by more accurate accounting of withdrawals through registration and metering of wells above a minimum capacity. This process would be assisted by more general regulation of drilling and drillers of wells.
- The overall data base on ground water could be improved if private energy developers (who possess site and facility specific information) and governments (which have larger, though more generalized, bases) had a more formal mechanism for sharing their information resources.

Use of ground water for energy production entails the possibility of environmental degradation; more needs to be known regarding prevention.

- There are physical conflicts inherent in the use of ground water for energy or any other purposes; these include stream flow reduction, habitat destruction, saline intrusion, and subsidence. It is important to recognize that in many cases these cannot be prevented, but merely mitigated.
- Analysis of these effects is difficult because much more is known about the cost of control measures than the benefits of mitigation.

Saline ground water, deep ground water, and dewatering of mines offer alternative sources of supply, but have associated problems.

- The energy industry can reduce conflicts associated with ground water use by using those waters generally considered less desirable: saline or brackish water; water from deep aquifers; or water from dewatered mines.
- The relatively high cost of using these waters means they would never be used by agriculture for irrigation.
- Costs of treating saline or brackish water for cooling purposes compare favorably with the costs of dry towers.
- In many instances, deep aquifers without good hydraulic connection to streams may offer "new water" insofar as it is only economically recoverable for energy purposes.

Legal rules governing ground water are evolving constantly and vary greatly among jurisdictions; this complicates decision making, analysis, and management.

- The wide variations in the legal treatment of both surface and ground water create conflicts not only in

resource use, but also in planning efforts and in assessment functions such as those of OTI.

- In many States there are no mechanisms to facilitate the sale, lease, or transfer of water rights. In many Eastern States common law water rights doctrines forbid the transfer of ground water from the overlying land. A number of Western States, in theory, permit water rights transfers, although such transfers can be difficult to effect in practice. Finally, some States that permit transfers lack the mechanisms to protect third parties from the adverse effects of changes in types of use, place of withdrawal, or return flow.
- The control and management of replenishable ground water is not like the extraction of minerals in place, or like the removal of sand and gravel.
- A detailed analysis of law and policy conflicts between Federal, State, and local governments is needed as a first step toward rationalizing conflicting mandates at all levels.
- There is a need for an orderly resolution of reserved rights questions that relate to Indian tribes and to Federal property.
- Private parties in the ground water and energy process would be able to improve their planning and operations, and to better play a productive role in assessment activities, if governmental regulations were to become more definite and more predictable.
- Perceptions of the form of an optimal permit system are diverse, and involve combinations of the following elements: flexibility; formalized preference for certain uses (e.g., domestic); ease of transfer; or review and renewal processes after periods ranging from 10 to 30 years.
- Some participants favored a centralized adjudicating agency to resolve legal, economic, and policy conflicts; many participants were opposed to such an authority.

Economic bidding resolves some conflicts, but cannot accommodate others, such as third party effects or skewed financial resources of bidders.

- Third party effects may arise from transfer of water rights. For example, reducing water applied in irrigation will usually reduce return flows that, in turn, may

reduce ground water recharge. In such cases, downstream users may have inadequate financial resources or legal standing to protect their water rights.

- Because the energy sector has a vastly greater ability to pay for water than irrigators or other users, these conflicts are likely to increase.
- It is difficult to value the use of water for energy today compared to the value of water for alternative uses in the future.

Management of ground water resources is complicated by lack of uniform practices, goals, policies, and interests.

- The Federal Government will have to accommodate the problems occasioned by conflicting State water laws and policies that change from State to State.
- A rationally uniform approach to dealing with ground water and energy issues would be cumbersome; efforts should be aimed at smaller aggregations, such as regions or subregions, or areas where surface and ground water bodies cross State boundaries.
- The differential reservation of ground water for pre-selected purposes, such as municipal supply, might simplify planning and lessen disputes.
- If a greater effort were made to secure reasoned, supported arguments from interested groups, a very large proportion of possible conflicts could be avoided, or at least anticipated, by policy formulators, legislators, and decision makers. In addition, the information generated would assist assessment efforts.

The Department of Energy needs to more explicitly chart and publicize its policies that affect water.

- The Department has a major role to play in a range of activities involving water resources, and should firmly establish policies governing this role.
- There is currently a less than complete understanding of DOE's role and policies among the public at large, and the water and energy communities in particular.
- A better understanding of the scientific and technical aspects of ground water and energy issues by DOE decision or policy makers would help resolve various problems.

WHAT IS THE NATION'S GROUND WATER STOCK?

(The Supply Issue)

Nearly every imaginable energy system demands water for one or more process elements, ranging from process feed, to cooling functions, to waste treatment. Because of this fact, technical, economic, legal, and policy decisions regarding energy will make significant impacts on the future condition of our nation's water resources.

The Magnitude of the Resource

One of the primary conclusions of the U.S. Water Resources Council's recently completed Second National Water Assessment was that water supplies are generally sufficient to meet current water needs for all beneficial purposes, but local shortages exist. The Comptroller General's January 1980 Report to the Congress, "Water Supply Should Not Be an Obstacle to Meeting Energy Development Goals," supports this conclusion in regard to energy development. However, the Council's Assessment shows that increased energy demands are creating new problems in terms of both quality and quantity. This is particularly important in certain water-short regions, which experience ground water, as well as surface water, supply problems. Energy development in these areas may require a number of tradeoffs, weighing water demands for energy against demands for other purposes (for instance, agriculture). Such tradeoffs could have a profound effect on the present social order.

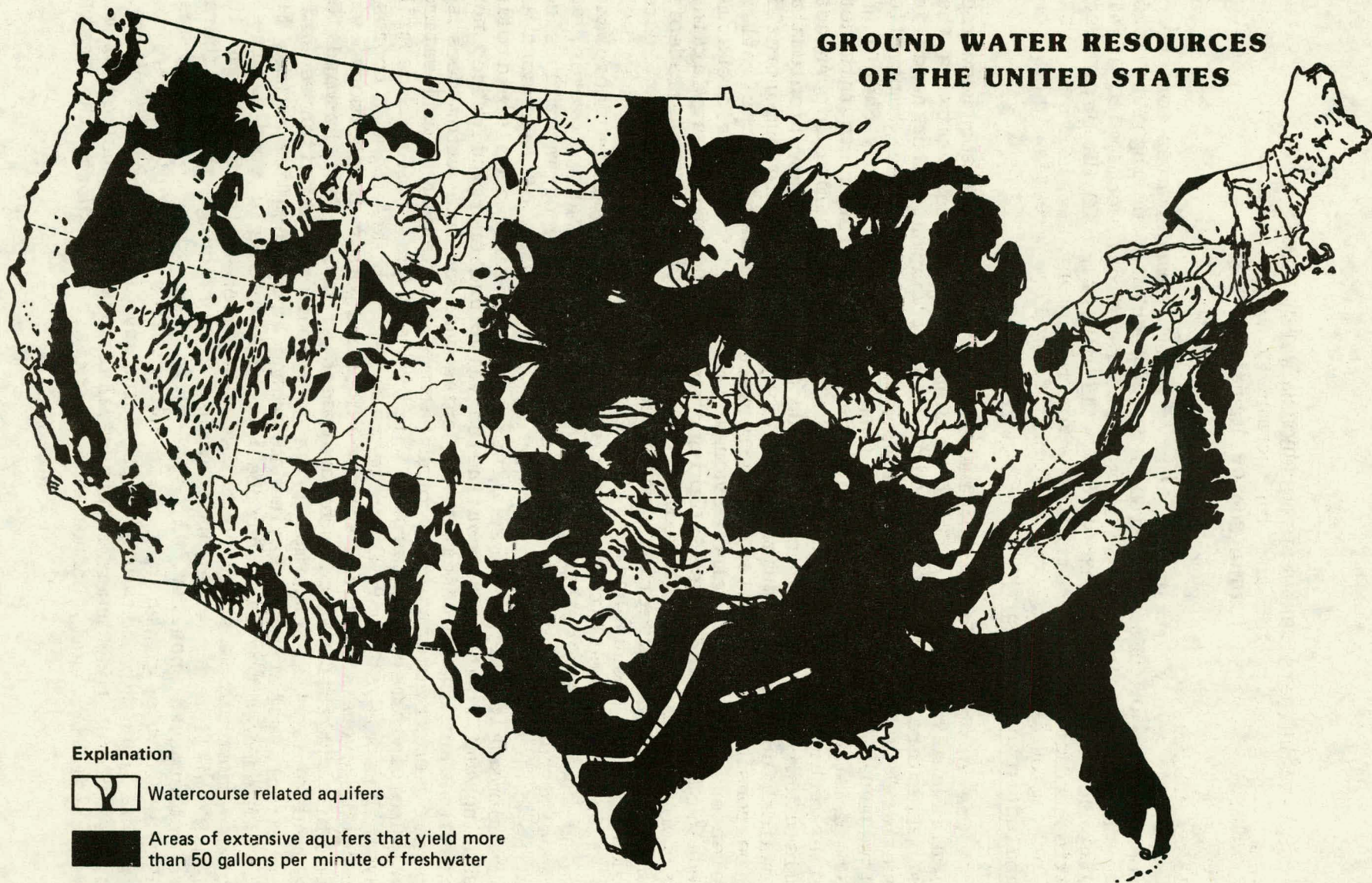
A wide range of issues are related to the questions of water supply and energy development. Among the most important, however, are those hinging on the fact that a nationwide abundance of water does not lessen the problems of localized shortages. Problems of this sort are often overlooked in key analyses, such as the referenced Comptroller General's report. A bright spot in the water and energy picture, however, is the fact that a localized shortage of surface water does not necessarily mean a shortage of ground water, thus making ground water a viable source in some instances.

The overall national supply of ground water is enormous, with approximately 200 billion acre-feet located within a few thousand feet of the land surface. Furthermore, its geographic distribution is extensive, with only a few areas having no ground water supplies. (See Figure 1.) Ground water has long been recognized as a good source of water, as shown by the fact that fresh water withdrawals in 1975 totalled 92 million acre-feet nationwide. A portion of these withdrawals are replenished annually.

A given ground water supply in any area, however, must be "available" for desired uses. This availability is a function of many factors--physical, legal, economic, and social. In short, the test of

FIGURE 1

**GROUND WATER RESOURCES
OF THE UNITED STATES**



Explanation



Watercourse related aquifers



Areas of extensive aquifers that yield more than 50 gallons per minute of freshwater



Areas of less extensive aquifers having smaller yields

SOURCE: U.S. WATER RESOURCES COUNCIL

availability might be stated as the physical/technical ability to withdraw water from an aquifer and the community acceptance of this withdrawal, as manifested in incentives or impediments.

Information Needs

Information needs regarding ground water and energy include the following areas: the magnitude and location of the resource; its availability; and process demands for (and impacts on) the resource. Information on ground water resources is much more complete on a national or regional level; local information varies greatly in uniformity, and often may not be available.

Futhermore, information needs for regional assessments may be poorly defined and justified. This is closely tied to the ongoing need for DOE development of better methods of integrating, sharing, analyzing, and displaying ground water information.

Existing data bases need to be coordinated and strengthened, and better methods are required to translate data bases into products and tools usable by planners and decision makers. Keeping in mind that ground water is an integral part of the hydrologic cycle and normally cannot be considered separately from surface water, analyses of available water supplies must include an interpretation of the cycle that is tailored to the level of aggregation for projected energy demand (i.e., national, or regional). Moreover, many detailed and interrelating aspects of the hydrologic cycle under consideration must be accounted for, such as the amount and availability of otherwise less desirable (e.g., saline) waters and the dynamic effects of contemplated drawdowns.

The Role of Simulation

Simulation of ground water systems can offer a valuable means of assessing and framing alternative energy production and development strategies, as well as predicting the consequences of ground water uses in economic, environmental, and other terms. At local, and sometimes regional, levels of enquiry, ground water models are needed to describe the physical flow system and accurately predict the development process. Good models are currently available for this purpose. Furthermore, supporting data programs exist, such as the U.S. Geological Survey's Regional Aquifer System Analysis (RASA); these should all be used to a greater extent and strengthened as necessary. Appropriate models have been developed over the past decade, and it is unlikely that users will encounter situations in which nonavailability hinders predictions.

There are, however, differences in perceptions of the adequacy of modeling in the ground water and energy area. In all cases, data requirements should be established that include, at a minimum, the following parameters in defining the physical framework:

- A geologic map showing areal extent and boundaries of aquifer.
- A topographic map showing surface water bodies.
- Water table, bedrock configuration, and saturated thickness maps.
- A transmissivity map showing areal distribution of transmissivity.
- A map showing the variation in storage coefficient in aquifer.
- The relation of transmissivity to saturated thickness.
- The relation of streams to aquifers (hydraulic connection).

Moreover, to calibrate and develop the model, the following data should be available:

- Recharge in time and space (irrigated areas, recharge basins, recharge wells).
- Surface water diversions (time and space).
- Ground water pumpage in time and space (historic and current).
- A depth-to-water map (with evapotranspiration rate).
- Tributary inflow (time and space).
- Ground water inflow and outflow.
- Precipitation.
- Distribution of water quality in aquifers.
- Stream flow quality (time and space).
- Water level change maps and hydrographs.
- Stream flow measurements of gains and losses.

WHAT ARE THE BARRIERS TO USE OF GROUND WATER RESOURCES FOR ENERGY PRODUCTION?

(The Conflicts and Barriers Issue)

Ground water, like all other needed resources, is subject to a wide variety of potential conflicts among competing uses. The types of conflicting uses are diverse, including energy production, municipal supply, agriculture, industry, recreation, and environmental protection (both habitat protection and pollution control). Rather than being easily predictable, the details of these conflicts are complex and constantly change in response to localized situations that are, in turn, shaped by local, State, and Federal policies and needs. As national policy gives energy production a high priority in comparative hierarchies, existing conflicts will become magnified. Conflicts and barriers in the area of ground water and energy production are, however, amenable to a degree of categorization and can be enumerated in a general way.

Conflicts and Barriers Relating to the Legal System

One of the key areas of conflict in the field centers on the legal regime for allocating resources. This system, which has evolved over the years, is far from being homogeneous. In fact, it has developed along several paths--Federal versus State rules, Eastern versus Western rules, and surface versus ground water rules. The last of these has special significance since the dichotomy in legal rules does not match the physical similarity and occasional interrelation between surface and ground water. Thus, efforts at conjunctive management are currently impeded by overlapping and conflicting rules.

Another key conflict in the legal realm concerns the use of water as a substance, as opposed to the use of water as a mechanism or medium for other purposes. For instance, restrictions on base flow withdrawals--aimed, for example, at protection of wildlife habitats--will limit the use of underlying aquifers.

An area where policy and law overlap involves the quality versus quantity aspects of water resources management. Current administration of these two aspects by different agencies is the cause of widespread conflict. Likewise, the separation of ground water withdrawals and storage is an area involving disjointed approaches to management. At this time, the law does not facilitate the promotion of artificial recharge, and uncertainty about the right to recapture recharged water represents a major problem. Overall, the wide variation in the ways that State legal systems deal with both surface and ground water not only creates conflicts in resource use, but also makes planning efforts and assessment functions (such as those performed by OTI) more difficult.

One of the most pressing legal topics in the ground water and energy area concerns the role of the Federal Government and Indian tribes with regard to private, State, and local activities. Over the years, a legal rule has evolved to the effect that some surface waters on Federal or Indian lands were "reserved" and therefore outside State control. In recent years, there has been a parallel development with regard to ground water.

In many States, there are no mechanisms to facilitate the sale, lease, or transfer of water rights. For example, in many Eastern States, common law water rights doctrines forbid the transfer of ground water from the overlying land. A number of Western States permit water rights transfers in theory, but they can be difficult to effect in practice. Finally, some States that permit transfers lack the mechanisms to protect third parties from the adverse effects of changes in types of use, place of withdrawal, or return flow.

Fundamental interjurisdictional issues are also of great importance. Significant management and legal questions exist not only in single jurisdictions (such as a State), but also in areas where aquifers cross State or national boundaries. In these areas, one is often faced with markedly dissimilar approaches to the use of resources. Experience in the United States with river basin or international commissions has been good, but it should be recognized that the experience in their use has been limited. For this reason, it should be expected that ground water-related conflicts will evolve, necessitating new approaches.

Conflicts and Barriers with an Economic Basis

A detailed analysis of economic issues is especially difficult, due to the lack of a solid base of information on costs, especially nonmarket costs. This lack of information is manifested in the complex relationship between various "payers" and "beneficiaries," competing uses with differing valuation systems, and fluctuating time constraints. Not only do these factors act individually, but their interactions create extremely complex situations, often impeding the optimal use of ground water resources.

Another economic conflict arises from the question of using ground water for energy production today as opposed to saving it for alternative uses (including energy) in the future. For example, in areas of nonreplenishable ground water supplies, decisions will need to be made regarding rate of development and long-term scenarios concerning rates of depletion. Similarly conflicts may arise in comparing the benefits of water quality protection with the costs of restricted energy production. A key difficulty appears to be that we know a great deal more about the cost of control than about the benefits of mitigation.

Economic conflicts are inherent in choosing among ground water use alternatives, e.g., environmental improvement versus municipal,

agricultural, industrial, or energy uses. This is a highly significant conflict in areas of the West where overdrafts of ground water already occur.

Furthermore, conflicts in the form of third-party effects may arise from market imperfections in water transfer. For example, reducing water applied in irrigation will usually reduce return flows, which, in turn, may reduce ground water recharge. In such situations, historic or potential users may have to incur legal costs to protect their rights or increased costs for alternate water supplies.

Policy Based Conflicts and Barriers

A significant policy based conflict occurs when Federal policy --as manifested in aid programs or legislative mandates--encourages the use of ground water in contravention of State or local interests. Federal efforts to expedite procedures via "red tape cutting" (for instance, the proposed Energy Mobilization Board) are destined either to create intergovernmental friction by their success, or to be so ineffective that they are useless. By the same token, State and local governments often enact laws and regulations implementing policies that are contrary to Federal interest. In addition, political divisions may not only cause policy conflicts, but also more technical problems such as the gathering and compiling of comparable data for areas crossing State boundaries.

Physical Conflicts and Barriers

Environmental conflicts directly relating to the physical integrity of the ground water resource are widespread when parallel uses are less than fully complementary. For instance, aquifer degradation may be caused by contamination from chemicals released during in situ processing, extractive activities, or deep well disposal of toxic wastes.

Since ground water is inextricably part of the local hydrologic system, the ground water regime is often connected to the surface regime. On the one hand, in periods of low flow, streams are frequently fed by ground water. On the other hand, low flow in streams might be caused by ground water withdrawals. In this case, extraction of ground water to the point where the water level is below the stream bed could result in no flow during drought periods. Such elimination or reduction in stream flow could have serious adverse consequences (e.g., elimination of natural springs; loss of wetlands, recreational opportunities, waste assimilation capacity, and fish and wildlife habitats; or injury to fragile ecosystems, including loss of endangered species, scenic and esthetic values, and downstream uses). Further environmental harm might result from the fact that many energy processes consume relatively pure water and the diluting power of return flow is decreased, resulting in

build-up of excessive salinity or toxic concentrations. On the other hand, in periods of low flow, streams are frequently fed by ground water.

Issues of National Defense

The introduction of national defense considerations into any decision-making process involving ground water and energy severely complicates the process. For instance, in vast areas of the West, a strong possibility now exists that ground water supplies will not only be sought by energy, municipal, and agricultural interests, but also by the military for the development of the MX Missile System. Likewise, severe limitations on access to supplies by other users are likely.

It is fairly safe to predict that energy production in the United States will continue to generate conflicts over ground water use. New national policies that give energy the foremost position in comparative hierarchies and the massive amounts of capital available for energy production will accelerate these clashes. Thus, instead of a continuation of traditional conflicts among water uses (such as those that have evolved over the decades), there is likely to be a sharp turn in user relationships, with many more of the economic bargaining chips going to energy producers. At that point, any existing conflicts will become greatly magnified.

WHAT OPTIONS ARE OPEN FOR THE USE OF GROUND WATER FOR ENERGY PRODUCTION?

(The Alternatives)

While the list of potential conflicts and barriers to the effective use of ground water may appear formidable, various alternative courses of action are available to minimize problems. The use of ground water for energy production is a viable option in several respects. The utility of ground water in any given case depends on its quality, cost, and availability. These, in turn, are determined by a range of technical and institutional factors involving issues of information, planning and regulation.

Use of Less Traditional Ground Water Sources

Less desirable water can be used effectively in areas where there is no supply of high-quality water or as a supplement to high-quality sources. For example, ground water high in dissolved solid concentrations offers a relatively attractive alternative for use in some process components such as cooling systems. Similarly, such saline water can be used for ash sluicing, flue gas scrubbing, or for transporting materials in slurry pipelines.

These lower-quality waters can sometimes be used in their natural condition, or they can be treated. Costs are fairly reasonable and the technology is available; electrodialysis, for example, is an effective process that has been successfully used on large volumes of water.

The use of deep aquifers constitutes a large source of ground water of varying quality; high drilling costs and the lack of an immediate need, however, have thus far discouraged their use. Significant quantities of water can be obtained at mines and mineral processing facilities; this water represents the otherwise unwanted by-product of dewatering operations. Because of the relatively high cost of using these less desirable waters, there is little competition for them. Agriculture would never use them. Thus, potential conflict is avoided if energy processes make use of these sources.

Development of a Better Information Base

Also related to the use of aquifers is the fact that many supplies of ground water have been uncharted and unmeasured. A large number of aquifers are not directly connected to surface streams subject to flow gauging. Therefore, the magnitude and areal extent of these resources must be determined by drilling individual test wells. Because this process is sporadic, many regions have sparse data bases on ground water availability; additional test drilling would allow a determination of the extent of newly available quantities of water.

A better understanding of the scientific and technical aspects of ground water and energy production by government decision makers would go far toward resolving a host of problems. For instance, they need to know how aquifers may be linked to surface waters, along with the inherent benefits (e.g., recharge or low flow augmentation) and the detriments (e.g., interference with legally separate rights). Along the same lines, they need to understand the relationship between gauged surface water bodies and individual ground water aquifers to improve the oversight process. Many of the current problems relating to the use of poor-quality ground water could be resolved if there were a better understanding of its physics and chemistry. Likewise, decision makers need to know as much about the technology and cost of waste (degradation) prevention as they do about the technology and cost of cleanup methods.

Collection of new data to develop hydrologic characterization of major aquifers could be assisted by consistent regulation of drilling and drillers of new or replacement wells. This could be supplemented by more general accounting of withdrawals through regular registration and metering of wells above a minimum capacity. Such regulation might be accomplished through legislation that establishes a permit procedure to protect existing uses, as well as to gather data. This is especially important in areas of minimum recharge or in mined aquifers that will be depleted within a determined period. Permitting, licensing, or regulation systems must be flexible, but with preferential consideration possible for specific uses such as domestic purposes. Some participants proposed that permit systems include provision for review and renewal after 10 to 30 years; on the other hand, others felt that permits should be readily transferable.

Research could yield information relating energy facility requirements to local water parameters, economic factors, and transport mechanisms. The use of combinations of different quality waters in different (or even the same) parts of a process should be further investigated. A more detailed knowledge of the economic and other costs associated with ground water and energy production decisions and tradeoffs will ease some of the conflicts involved in decision making. As the quality, extent, hydraulic linkages, and recoverability of the water in an aquifer become better known, the impacts of proposed development (as well as related technical and institutional constraints and solutions) can be progressively identified, assessed, and addressed through planning and regulation.

Improvement of the Legal and Management Regimes

Conflicts caused by shared ground water resources might be lessened by informal communications between adjoining jurisdictions. A more thorough understanding of the problems and issues underlying ground water and energy production is needed for policy and planning options. However, a uniform approach to dealing with ground water and energy

issues nationwide will not work. Efforts should therefore be aimed at smaller aggregations, such as regions or subregions. In addition, this localized approach must focus on traditional problems caused by studying the quality and quantity aspects of ground water separately. This conflict would be eased somewhat if there were a firm commitment that future efforts would not relate to just one of these aspects, but would rather focus on both. For example, when there is a choice of water supplies, certain quantities of high-quality ground water might be reserved for preselected purposes such as municipal supply, thus lessening planning problems.

Issues arising from the concurrent consideration of water quality and quantity could be more easily addressed if more use were made of agreements among oversight agencies, such as network arrangements. These arrangements might include mechanisms such as the acceptance of prior permit certifications. This cooperation could also extend to the private sector. Specifically, the overall data base on ground water would be improved if private energy developers (who possess site and facility information) and governments (which have larger, though more generalized, bases) could share their resources. Recognizing that proprietary information would have to be protected and that large investments in unique information might be at least partially repaid, a mutually beneficial relationship between the two sectors could be established.

There is widespread recognition that the resolution of certain legal problems will, in turn, help to ease many potential conflicts. For instance, a detailed analysis of Federal policy that is contrary to State or local law and policy must be performed as the first step toward rationalizing conflicting mandates at all levels. Likewise, there is a growing need for the orderly resolution of reserved rights questions that relate to Indian tribes and to Federal property. Furthermore, any new legislation must complement and strengthen water quality laws by encouraging reuses and mandating the control of waste, by encouraging ground water recharge (and storage), and by stimulating interstate and regional cooperation.

Increasing the certainty and predictability of laws and regulations also could be important in allowing private parties in the ground water and energy process to improve their planning and operations. Many current and potential conflicts in the field can be traced to an inadequate process of dispute settlement. This process has too often been developed by analogy from other areas of concern. The control and management of rechargeable ground water aquifers are not like the extraction of in-place minerals or like the removal of sand and gravel.

Conflicts over policy could be handled within the planning context, either through an independent planning group (although this is often not feasible) or by establishing a planning group in the executive

office of the governor. Furthermore, many legal, economic, and policy conflicts can be resolved by the use of a centralized adjudicatory agency, such as the one established under the Florida Land and Water Management Act.

Many conflicts would be avoided, or at least mitigated, if policy formulators, legislators, and decision makers were able to secure reasoned (and supported) arguments and ideas from local or other interest groups before taking action.

The increased availability of data would assist in preparing assessments, performing analyses, and developing information bases. Vital to this process would be the use of a standard valuation system that recognizes both present and future costs and benefits for all possible ground water and related land uses, as well as those related to external impacts. Such a system would make the assessment and policy-making functions easier and more productive. One possible outcome of this system might be that policy makers could rank alternative uses for scarce water resources. It might then be possible to aid all users in competing fairly in the marketplace.

Development of Decision-Making Aids

Finally, consideration must be given to the needs of the individuals who are involved in the actual energy development processes. As shown by the range of issues discussed in the preceding sections, the process is complex, to say the least. A simple checkoff matrix has been developed to broadly outline the decision-making process for water uses. It is included here as Figure 2. The left-hand column shows various water sources or ways in which water needs can be met. For any given assessment, it is expected that a small number of candidate sources can be identified from the checklist. For the sources selected, each would be examined (in order of anticipated cost) until the analyst is satisfied that sources have been identified that can provide the needed water at the lowest cost, given the conditions of legal availability and environmental and social acceptability. In some cases, all the water needed might be available from one source; more frequently, tradeoffs will have to be made among sources to determine the best strategy.

A more detailed matrix could be developed to help decision makers answer questions regarding the water supply for energy development on a regional or site-specific basis.

Figure 2

CHECKOFF MATRIX TO IDENTIFY THE ATTRIBUTES OF
GROUND WATER PROBLEMS

SOURCES OF WATER	Physical Avail.	Reliability	LEGAL RIGHTS			ENVIRONMENTAL FACTORS			Cost	Social Accept.	Other
			State Laws	Purchase	Federal	Water	Air	Land			
<u>Surface Water</u>											
● Local											
● Imported											
<u>Ground Water</u>											
● Shallow Local Aquifers											
● Deep Fresh Aquifers											
● Deep Saline Aquifers											
● Imported											
● Mined											
● Sustained Yield											
<u>Process Changes</u>											
● Dry Cooling											
● Recycling											
● Reuse											
<u>Process-Derived Water</u>											
<u>Technology Substitution</u>											
<u>Weather Modification</u>											

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Appendix I

GROUND WATER FOR ENERGY PRODUCTION: AVAILABILITY, CONFLICTS AND ALTERNATIVES

CORE ISSUES

I. Ground Water Supply

WHAT IS THE NATION'S GROUND WATER STOCK IN TERMS OF QUANTITY AND QUALITY?

What ground water information is needed by DOE to make regional assessments and national projections? How does this differ from site analysis for individual energy facilities? Where, if any, are the regions of little or limited data? What are the needs for additional data gathering systems? How could these be implemented for maximum data procurement in a minimal time frame? How adequate are current modeling capabilities for analyzing ground water resources for various developmental proposals? How adequate are these models for assessing the impacts on surface water systems or ground water use systems? When there are differences in perception of the adequacy of data modeling, what is the nature of the differences? Why do they occur? What should DOE do in regard to data and data analysis of ground water supplies: In the long term? Immediately? In the intermediate period?

II. Conflicts and Barriers

WHAT ARE THE BARRIERS TO USE AND DEVELOPMENT OF THE NATION'S GROUND WATER RESOURCES FOR ENERGY PRODUCTION?

What are likely conflicts among sectors, such as municipalities, agriculture, other industry? How will these conflicts evolve when energy production variables are included? What are possible effects on the environment, for instance: land subsidence, salt water intrusion of aquifers, disruption of aquifers already in use, long run depletion of stocks, and effects on fish, wildlife and other ecological systems? What are some likely effects on surface water, i.e., problems of conjunctive use? How expansive is the range of conflicting and unresolved legal, regulatory, economic/financial, political and social issues?

III. Alternatives and Solutions

WHAT ARE THE TECHNOLOGICAL AND INSTITUTIONAL OPTIONS OPEN FOR USE OF GROUND WATER FOR ENERGY PRODUCTION? WHAT IS THEIR TECHNICAL, FINANCIAL AND ENVIRONMENTAL FEASIBILITY?

How can supply be increased, using such methods as: development of deep aquifers that cannot be economically exploited for traditional water use; development of saline or brackish aquifers whose dissolved solids concentrations preclude irrigation, public supply, or usual industrial uses; and salvage and redistribution of water associated with mine dewatering or oil shale development? Might there be sharing of aquifers which are already tapped? To what degree can there be utilization of ground water-surface water interchange systems? Is it feasible to import ground water from distant areas? Should there be selective location of generating stations in areas of high ground water potential? Can technological processes be used to reduce water demand? What are the institutional options, whether traditional or innovative, which hold the most promise for resolving conflict in ground water use by energy? How should DOE take technological options and institutional factors into account in its regional and national assessments and policy recommendations?