ORNL/M--4951

CONF-9406399--Exec. Summ.

Integrated Assessment of Climate Change

Characterizing Key Policy Issues

Report of a DOE Workshop on the Integrated Assessment of Climate Change, Washington, D.C., June 1994

Contents

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February 1996

This workshop was organized by the Center for Global Environmental Studies of Oak Ridge National Laboratory in Oak Ridge, Tennessee. The Laboratory is managed by Lockheed Marietta Energy Systems, Inc., for the U.S. Department of Energy under contract number DE-AC05-84OR21400.

Preface

A multidisciplinary, multiagency workshop was convened by the U.S. Department of Energy (DOE) in Washington, D.C., June 29–30, 1994. The goal of the workshop was to define key policy issues related to global climate change and the types of information pertaining to these issues that decision makers would find most useful.

The workshop was organized by the Center for Global Environmental Studies and the Environmental Sciences Division, both of Oak Ridge National Laboratory (ORNL), in cooperation with a steering committee composed of the following members:

Sumner Barr
Los Alamos National Laboratory
Don Wuebbles
Lawrence Livermore National Laboratory
Leonard Newman
Brookhaven National Laboratory
Gerry Stokes
Pacific Northwest Laboratory
Ruth Reck
Argonne National Laboratory
John Vitko, Jr.
Sandia National Laboratory
Nancy Brown
Lawrence Berkeley Laboratory

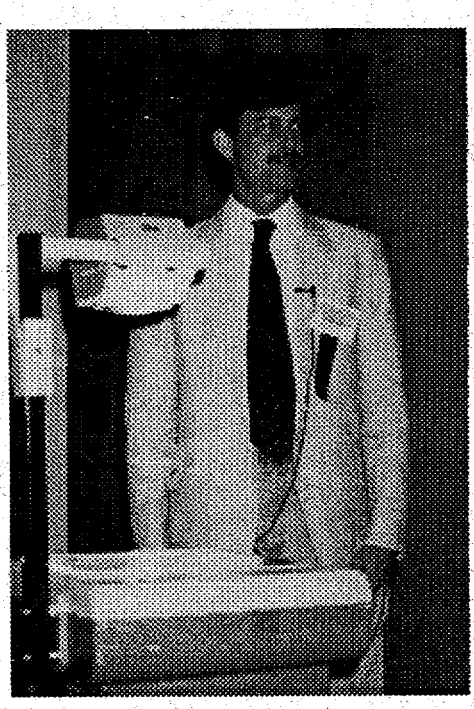
Several presentations were made to orient the participants and to give them a common experience base from which to start their discussions. Those presentations were:

Welcome and Integrated Assessment Status
Howard Gruenspecht
Director, Economic Analysis and Competition
U.S. Department of Energy
Usable Assessments
William C. Clark
John F. Kennedy School of Government
Harvard University
Integrated Assessment Plans and Challenges
John C. Houghton
Office of Health and Environmental Research
U.S. Department of Energy
Characterizing Key Policy Issues for Integrated Assessment
Virginia H. Dale
Oak Ridge National Laboratory
Paul N. Leiby
Oak Ridge National Laboratory
Robert V. O'Neill
Oak Ridge National Laboratory
Robert S. Turner
Oak Ridge National Laboratory
Alan Sanstad
Lawrence Berkeley Laboratory
David G. Streets
Argonne National Laboratory

To foster discussion, the workshop participants were divided into breakout groups made up of members with varied backgrounds and interests. These groups conferred independently to identify and define what they considered to be the key global-change policy questions that should be addressed by integrated assessment. The moderators of these breakout groups were:

Rick Bradley
U.S. Department of Energy
Nancy Brown
Lawrence Berkeley Laboratory
Hadi Dowlatabadi
Carnegie-Mellon University
Barry M. Lesht
Argonne National Laboratory
Roberta B. Miller/Thomas M. Parris
CIESIN
William P. Pennell
Pacific Northwest Laboratory

As the workshop progressed, the leaders of the breakout groups gave periodic reports on the discussions being held. In addition, an overnight newsletter summarized the proceedings of the first day for the participants. After the main workshop concluded, the steering committee gathered to review, critique, and focus what had transpired. This report summarizes the issues that the participants felt were critical in conducting integrated assessment of global climate change.



On behalf of the Environmental Sciences Division and the Center for Global and Environmental Studies of Oak Ridge National Laboratory, I would like to thank John Houghton of the U.S. Department of Energy's Office of Health and Environmental Research, Environmental Sciences Division; members of the Steering Committee; the speakers; discussion rapporteurs; and participants for their contributions to this effort to understand the integrated-assessment process and the role that it can play in investigating potential responses to global climate change. I would also like to thank Fred and Laura O'Hara for their outstanding work in producing the overnight newsletter, the executive summary, and the final report of the workshop.

Robert S. Turner
Environmental Sciences Division and the
Center for Global Environmental Studies
Oak Ridge National Laboratory

DISCLAIMER

Executive Summary

The workshop "Integrated Assessment: Characterizing Key Policy Issues." was held June 28-29, 1994, in Washington, D.C., with more than 90 participants. Introductory presentations explained the importance of integrated assessment of global climate change for the evaluation of potential mitigation and adaptation strategies and presented a framework for characterizing its key policy issues. The participants met in six discussion groups before reconvening in plenary session to review their findings.

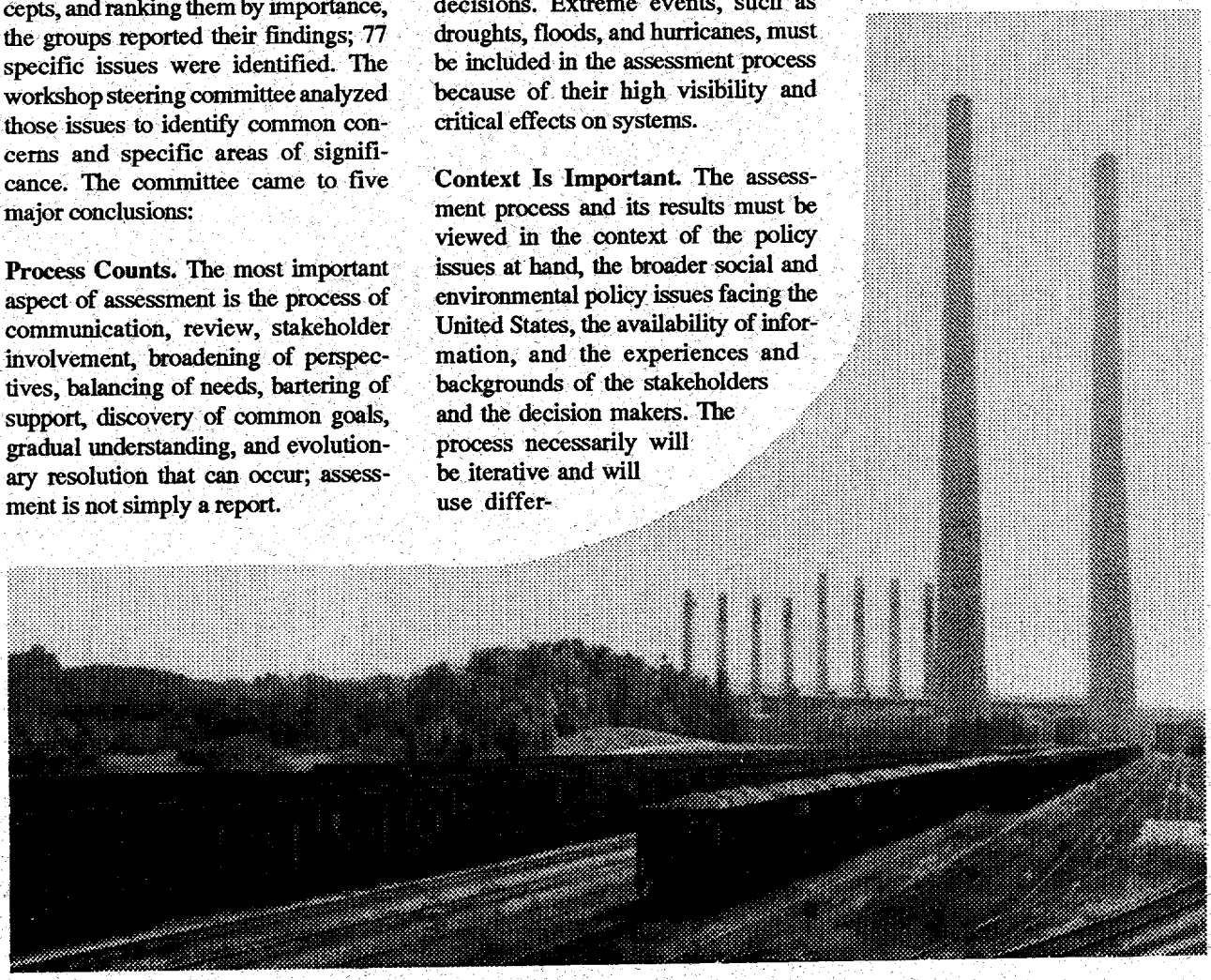
The discussion groups suggested and analyzed literally hundreds of issues about the process of integrated climate-change assessment. After developing these ideas, combining similar concepts, and ranking them by importance, the groups reported their findings; 77 specific issues were identified. The workshop steering committee analyzed those issues to identify common concerns and specific areas of significance. The committee came to five major conclusions:

Process Counts. The most important aspect of assessment is the process of communication, review, stakeholder involvement, broadening of perspectives, balancing of needs, bartering of support, discovery of common goals, gradual understanding, and evolutionary resolution that can occur; assessment is not simply a report.

Multiple Approaches Are Needed. The assessment process must use a variety of approaches with fundamentally different assumptions, with a wide range in focus, and with differing levels of analytical sophistication (from back-of-the-envelope calculations to different kinds of end-to-end modeling). Scenario effects across a range of indicators need to be compared, augmenting analyses that simply weigh a limited number of economic and social costs against concomitant economic and social benefits.

Effects Dominate. Perceived ecological, social, and economic consequences of global climate change will determine the most pressing need for integrated assessment in support of policy decisions. Extreme events, such as droughts, floods, and hurricanes, must be included in the assessment process because of their high visibility and critical effects on systems.

Context Is Important. The assessment process and its results must be viewed in the context of the policy issues at hand, the broader social and environmental policy issues facing the United States, the availability of information, and the experiences and backgrounds of the stakeholders and the decision makers. The process necessarily will be iterative and will use differ-



ent approaches as it evolves. A key to success will be hiring people who can step across organizational and disciplinary boundaries to provide lines of communication among the decision makers, stakeholders, and scientist/assessors.

Uncertainty Must Be Characterized. The assessment process must allow all participants to develop confidence in the process and to appreciate the uncertainty inherent in its outcomes. Uncertainty must be considered in a meaningful way and clearly communicated to lay audiences.

The workshop participants found the task of characterizing key policy issues difficult because of the complexity and situational nature of the problem of global climate change. At the same time, they were enthusiastic about the wide range of policy issues discussed; the intensity of thought; and the concept of viewing assessment as an ongoing process of analysis, synthesis, communication, and negotiation. The participants came to the realization that there is no single, right way to perform integrated assessment. Instead, the assessment process must respond to specific groups, each of which has a unique set of information needs, values, and motivating interests. The workshop made plain the tasks ahead for the integrated assessment of global climate change:

- Identify the decision makers, the stakeholders, and the assessment teams.
- Engage the participating groups in dialogue so they can understand one another's interests, needs, capabilities, and pressures.
- Determine (1) the information that will satisfy those parties' needs, interests, and pressures and (2) the level of clarity or certainty with which each party can supply the information desired.
- Select and/or develop the tools needed for producing that information.
- Gather and analyze data; project the outcome of alternative policy scenarios; synthesize, compare, and qualify results; and effectively communicate the comparison to all the parties concerned.

The next steps needed are to flesh out this process and link appropriate assessment approaches to the evaluation of specific policy actions.

Introduction

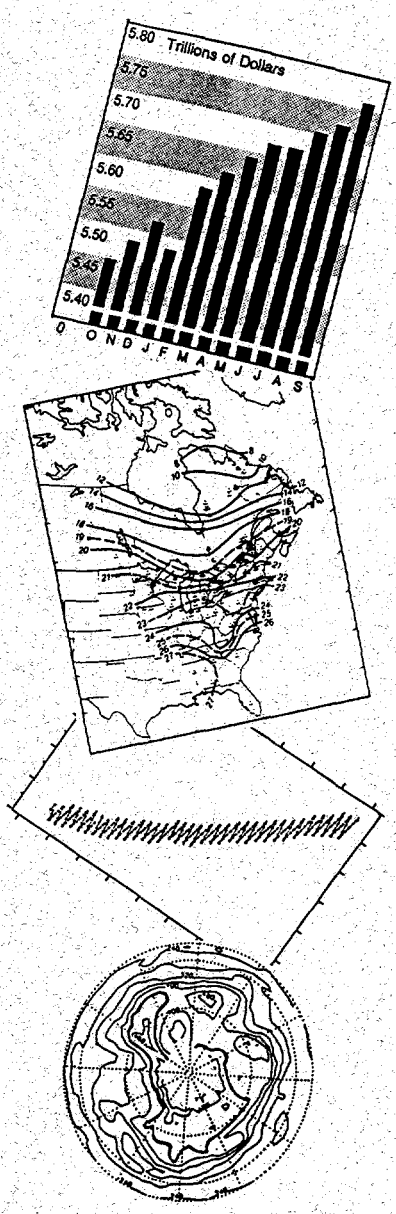
The workshop "Integrated Assessment: Characterizing Key Policy Issues," held June 28-29, 1994, brought together more than 90 participants from academia, the federal government, industry, and the research community. Participation was heavily weighted toward researchers who deal with the analysis of environmental problems.

The premise of the workshop was set forth at the beginning of the two days. Heretofore, scientific analyses of global climate change have been interpreted different ways, piecemeal and without much context, leaving the significance of those analyses open to various representations. Indeed, some findings have been contradictory: researchers have come down on both sides of the questions of whether the Earth's climate is actually warming, whether any warming might be caused by humans' activities or is just a part of a natural cycle of heating and cooling, and whether the infusion of carbon dioxide and other greenhouse gases into the air might significantly change the thermodynamic characteristics of the atmosphere. Moreover, some avenues of inquiry and concern have proved unfounded. These circumstances have led some within the policy community to question the meaningfulness of the concern about global climate change.

In addition, consideration of the effects of global climate change has generally been limited to the large-scale effects on environmental and economic systems: the net productivity of the oceans, the response of trees and forests to carbon dioxide fertilization and climate change, methane production by thawed tundra, and macroeconomic considerations of the gross world product. Little effort has been made to extend the consideration of global warming to human society and its interaction with the environment. For example, it is important to consider such questions as, What will be the effects of climate change on human health, on the spread of communicable diseases, on the dairy and meat supply system, on food and other cash crops, and on the demand for electricity and other energy sources? How will the costs of adapting to warmer climates be distributed among the peoples of the world? How will those costs accumulate and affect such measures of society as cost of production and labor productivity? How will global warming affect the cost of living in industrialized countries or the economic sustainability of less-developed countries? Will climate change produce hyperinflation? How will it affect markets for consumer goods? How will climate change affect health-care systems, population levels, employment rates, crime statistics, building construction rates, construction costs, and educational costs and opportunities? Such questions have not, by and large, been asked, let alone addressed.

For these reasons, global climate change should be assessed from a perspective wider than just the scientific, environmental, and macroeconomic approaches. Evaluating global climate change should take into account the ramifications on human health; food supply; population policies; regional and national economies; international trade and relations; policy formation and attendant political processes; national sovereignties; human rights; and international, interethnic, and intergenerational equity.

Such a broad approach to analyzing and dealing with international and global problems has come to be referred to as integrated assessment despite the fact that no such method has yet been clearly formulated, defined, developed, proved, and practiced. In such an approach, the scientific findings and projections would be integrated with social and institutional behaviors and expectations to produce an analysis of a future human society.



The Challenge

During the initial plenary sessions, the workshop participants were presented a view of the context within which global climate change policies are developed and assessed. The speakers at this plenary session described four generic models used to address major or global environmental problems:

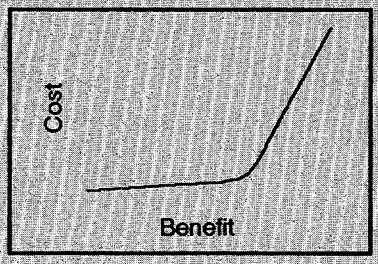
- A no-regrets policy;
- The elbow-in-the-cost-curve solution;
- The eliminate-the-cause-at-any-cost solution; and
- The interior solution, which strikes a balance between costs and benefits.

The Four Models

Environmental threats can elicit an infinite variety of responses, but four generic models cover the range. They differ in the economic, institutional, and political commitment made to limit or prevent environmental damage.

No Regrets. Some responses to global climate change, such as increased energy efficiency, have additional economic or social benefits. With such policies, a significant return on investment will be received whether or not the actions have any beneficial effect on global climate.

Cost-Curve Elbow. One response (and often the first approach tried) is to adopt measures that cost little or nothing and to stop or at least reassess the situation when the costs start to grow steeply. The decision point occurs at the elbow of the cost curve.



Any Cost. Dedication to the long-term preservation and improvement of the human environment may rally all available resources against any threat. Although limited by physical and economic realities, this approach essentially puts environmental concern before many (or all) of the other demands that exist for the use of society's economic, natural, and human resources.

Interior. This solution balances benefits against costs, and it weighs the need to preserve or improve the environment against the other needs of human society, such as education, health care, personal and property protection, national defense, recreation, transport, communication, and commerce. Within this matrix of demands, determining the value of the benefits and the dearness of the monetary and nonmonetary costs of taking some environment-related action is extremely difficult.

The U.S. policy on global climate change, as embodied in the Climate Change Action Plan, is to return U.S. emissions of greenhouse gases to their 1990 levels by the year 2000. A Beyond-2000 Plan is under development to maintain a downward trend in emissions. This policy is driven by international politics and is constrained by what is perceived as the elbow in the control-cost curve (i.e., it relies largely on voluntary actions that do not cost very much or that would be viewed as good business practices). This cost-curve approach may eventually evolve toward an interior-solution response, which requires the most demanding assessment process. But in the meantime, the ecological, economic, social, or institutional implications of the Climate Change Action Plan are not well defined. The plan has not received widespread public or scientific attention. The administration sees the plan as a prudent first step but recognizes that scientific research into global climate change must be made more relevant to assessment and policy development.

Integrated assessment could be a key approach to informing the policy-development process. There are many possible approaches to integrated assessment, from qualitative synthesis of back-of-the-envelope calculations to sophisticated, end-to-end linkage of atmospheric, ecological, social, and economic models. All of these approaches use an understanding of Earth's linked natural and human systems to project and compare the outcomes of alternative actions that could be taken in response to global climate change.

The challenge is to identify the decision makers who will lead and guide change, recognize the information that will be needed in the decision-making process, conduct the physical- and social-science research needed to fill those information needs, and present that information in a candid and understandable manner.

Historical Precedents

During the plenary sessions, speakers addressed the question "What makes assessments useful?" by analyzing the historical record of several assessments of large-scale environmental problems and of possible approaches to solutions for those problems. Examples of such assessments are the Intergovernmental Panel on Climate Change (IPCC) review of climate-change impact and the National Acid Precipitation Assessment Program (NAPAP). Studying the successes and shortcomings of these and other previous efforts can help improve our ability to conduct meaningful integrated assessments.

The evaluations of the results of previous integrated assessments indicate that

- Science-driven assessment must be distinguished from policy-driven assessment; our society invests too little too late in policy-driven assessment. Also, our society tends to get frustrated with scientific debates about impacts, truncates the dialogue, and focuses on impressions rather than on scientific facts. What is really needed is a broad information and intelligence system to make information accessible to the pluralistic group of people who will use and supply that information: corporations, town councils, regulatory bodies, utility boards, legislators, etc. In addition, stakeholders and others involved in the decision-making process need to recognize that policy-driven assessment can help lower concern as well as raise it.
- Assessment methods, especially those used in the United States, tend to focus on adverse impacts. They exhibit a preoccupation with valuation of benefits/costs versus comparison of policies/options across a range of indicators that are meaningful to policy makers and members of the general public.
- Assessments that are useful to decision makers are generally targeted at specific decision makers, localities, or political units facing narrow, specific choices; they reflect a pattern of narrow focus both in terms of targets of potential policy actions and in terms of the instruments that might be used to achieve the policy objectives; and they pay particular attention to the political conditions surrounding the decision.
- Not all decision makers have the same interests or are satisfied with the same observations. Rather, they require answers to a variety of questions and, therefore, need different types of assessments. So an integrated assessment should be pluralistic, encouraging multiple assessments directed toward the different interests, and using a variety of methods.
- The most-used assessments have responded to "what if" questions posed by decision makers in transparent, plausible ways. Therefore, what is needed are assessment approaches that can quickly and easily analyze and compare a variety of scenarios. But assessments often have to contend with contingencies and unanticipated turns of events. So the chosen assessment approach should be nimble enough to allow the modification of the underlying assumptions, the rapid recalculation of the results, and the swift reconsideration of the conclusions.
- Successful assessments use qualitative approaches when the limits of quantitative methods are reached.
- Successful assessments have communicated their findings as information that is understandable to the recipients.
- Some analyses have indicated that policymakers have not been strongly influenced by assessments. This apparent absence of influence may, indeed, be the case, or it may be a problem of perception. Either way, it is a question that should be dealt with.

Lessons Learned

Studies of previous assessments have provided several guidelines for designing and conducting integrated assessments:

- Assessments should be choice- and user-specific rather than comprehensive
- Premature closure of the debate on policy/response options should be avoided
- Nonintegrated assessments of portions of the problem at hand should be pushed to completion
- Analyses of costs and benefits should be supplemented with comparisons of policies/options across useful ranges of nonmonetary indicators.

One reason the scientific and policy-making communities are having such difficulty identifying an appropriate response to the question of global climate change is that the question itself is unprecedented in scope, scale, complexity, and potential severity of impact. As a result, the normal methods and paradigms for dealing with scientific problems (identification of critical experiments, funding of research, presentation of results, peer review, technical advice, political debate, and communal action) have broken down and have been ineffective in dealing with a problem of this magnitude.

Integrated assessment could be a key approach to informing the policy-development process

Integrated assessment has emerged as a general paradigm to guide scientific research on climate change and to formulate new and more effective policies in response to such change. But integrated assessment has three special attributes:

- It requires the integration of results from different disciplines on a balanced basis.
- It assumes the integrated analysis may not equal the sum of the parts.
- It requires a synthesis that is neither just linking together nor aggregating of individually provided parts or components.

These requirements may be met in part by the use of modeling, which provides a framework for assembling information from different disciplines; for making quantitative projections; for assessing gaps in information; and for determining risks, sensitivities, and uncertainties. However, modeling itself has some drawbacks:

- Large-scale models require simplifications in forms of data and interactions.
- Often, large-scale models also need to be linked with models representing other systems; as a result, the linked components may not have the same temporal or spatial scale or they may be mismatched in other basic assumptions.
- Within models, different people may value costs and benefits differently.

In addition, the process of decision making goes beyond the capabilities of models and may be decisively influenced by the current political climate, the state of knowledge, and individuals' perspectives (e.g., whether they are stakeholders, scientists, or decision makers). As a result, integrated assessment must be a process that provides a basis for (1) comparing alternative policy choices, (2) allowing policy issues to frame the direction of scientific research and development, (3) involving existing science knowledge, (4) accommodating new information as it becomes available, and (5) providing a bridge between science and policy. A conceptual framework for accomplishing all this is illustrated in Figure 1.

Such a framework for assessing the causes and effects of climate change and the implications of alternative policy responses leaves untouched many

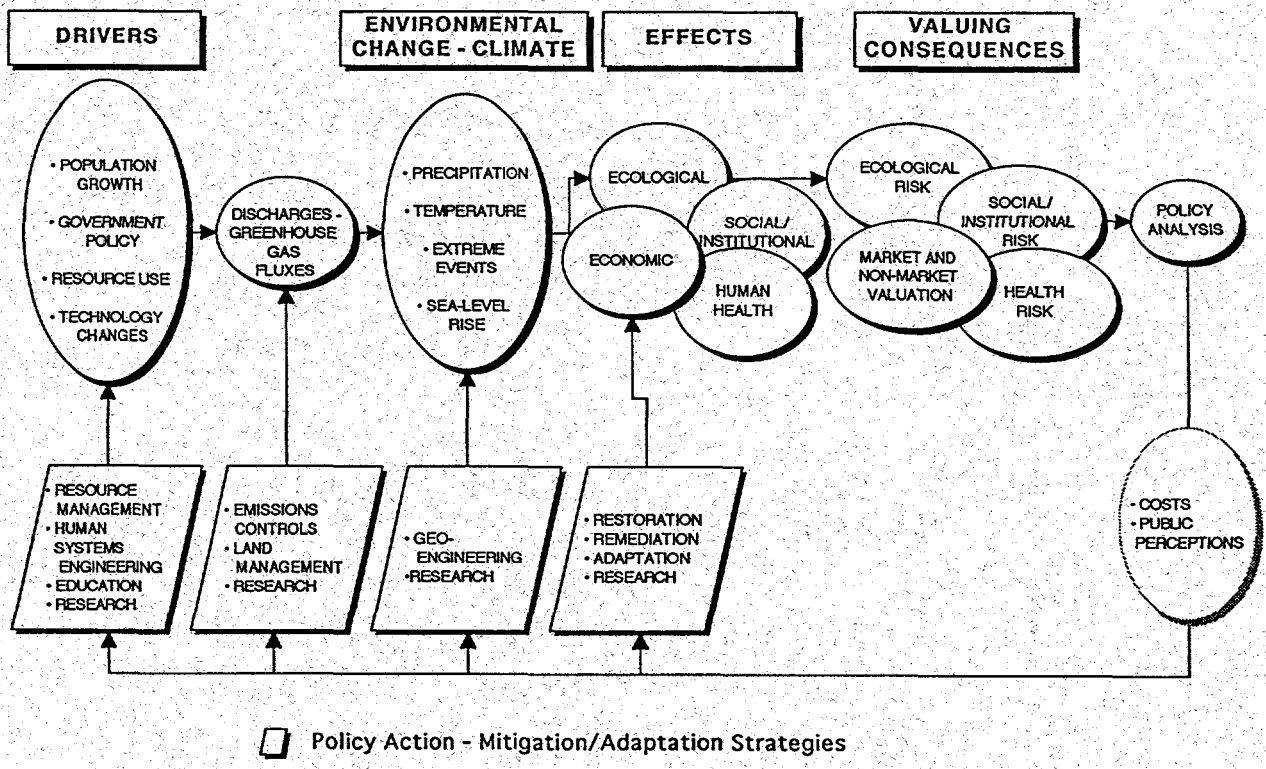


Figure 1. A conceptual framework for the integrated-assessment process for global climate change. In it, a number of drivers (population growth, use of resources, etc.) produce stresses on the functioning of the environment and/or of society. These drivers increase the introduction of greenhouse gases into the atmosphere. The increased greenhouse-gas concentration influences global climate, which in turn produces a variety of changes in forests, croplands, oceans, employment, consumer goods' prices, health, food supply, and political stability. These effects (or projections of changes) are perceived by individuals, interest groups, and institutions as changes and/or risks of change, depending on the magnitude of the climate change, the vulnerability of the affected population, and the social cohesiveness and organization present. Calls for action elicit analyses of what possible steps can be taken to alleviate the situation; the costs involved and the public perceptions of both the problems and the effectiveness of potential responses play important roles in the selection of options. Actions may be directed toward avoiding or reducing adverse effects, the climate changes, the emissions themselves, or the underlying causes of the whole problem. The process is iterative and not likely to be linear, involving many feedback loops not shown.

questions of how that process might proceed. A plan for implementing an assessment framework should include such issues as:

- What type of action might be pursued and what assessment tools might be used
- Who or what would be the audience for the assessment
- When the assesment might be conducted in relation to the onset of effects and the conduct of political debate
- What spatial scale might be employed
- How the widespread activities associated with the assessment and the accompanying political debate might be coordinated
- What the implications might be of public versus private action in responding to any particular threat posed by global climate change
- What the implications might be of voluntary actions versus prescriptive obligations in dealing with a given threat

The Workshop

Workshop participants were asked to consider assessment as a process of clarifying policy options that uses the scientific method, observations, understanding, and projections to assist the decision-making process by evaluating issues and by comparing alternative scenarios or outcomes of possible policy options.

Participants were given examples of policy questions, such as how much to reduce trace-gas emissions, whether to subsidize mitigative technologies or adaptation strategies, and how to address such concerns as equity issues. Breakout groups were challenged to identify and to characterize other key policy issues or response options from which appropriate assessment approaches and relevant research agendas could later be derived.

The question of global climate change is unprecedented in scope, scale, complexity, and potential severity of impact

The breakout groups had difficulty keeping separate or distinguishing between policy issues (such as mitigation or adaptation issues) and implementation issues (such as what topics are to be researched and who funds the effort) in an integrated-assessment process. Only a small number of the groups identified and characterized issues to be dealt with in designing integrated assessments dealing with specific aspects of global climate change.

Although participants found it very difficult to focus on specifics of the issues in their breakout groups, they were enthusiastic about the wide range of policy issues discussed; the intensity of thought; and the concept of viewing assessment as an ongoing process of analysis, synthesis, communication, and negotiation rather than as a model or report.

Some discussants thought the policy issues identified reflected a reactive posture; one suggested the need for more proactive activities, such as developing a "man on the moon" national resolve that would move the United States to a zero-net-carbon emission rate by some date. Such an activity could secure for the United States a leadership role and concurrently buy time for planning, infrastructure adaptation, and social and economic adjustments.

The breakout groups suggested and analyzed literally hundreds of issues related to the process of integrated assessment. After developing these ideas, combining similar concepts, and ranking them by importance, the groups reported their findings; 77 issues were identified and are listed on succeeding pages in shaded boxes near the text in which they are discussed. The workshop steering committee later analyzed those issues to identify common concerns, which are presented in the Conclusions section of this report.

Is There a Problem, and What Is Its Cause?

The first issue that has to be addressed is whether climate is changing and whether mankind's actions have any influence on that change. Global surface-air temperatures have been rising, with six of the warmest years of the century occurring during the past seven years. But how do we know that this warming is not part of a long-term climate cycle? Indeed, it takes catastrophic injections of particulate matter and sulfate aerosols into the upper atmosphere (e.g., by Mount Pinatubo in the Philippines) to produce noticeable declines in global temperature. And the El Niño and Southern Oscillation play an important role in determining annual precipitation across the middle of North America and over Southeast Asia. Is it defensible to say that the atmospheric effluents of human society (dusts, carbon oxides, nitrogen oxides, hydrocarbons, and chlorofluorocarbons) play a measurable role in determining the temperature of the atmosphere and the patterns of precipitation? The thesis that has been advanced by the scientific community during the past decade is that these emissions do, indeed, play such a role.

The scientific community is currently debating the merits of that thesis, and policymakers are considering how to cope with this potential threat. Additionally, all of the policy options for dealing with the issue come with some financial cost. A carbon tax to lessen emissions would engender inflationary pressures, hinder economic development, and lower the standard of living. Tilting the energy mix toward nuclear power may raise concerns about public safety, the transport and storage of nuclear wastes, and nuclear-weapons proliferation. Mitigation strategies (i.e., actions designed to minimize or eliminate causes of global climate change) raise questions of costs, inflationary pressures, and secondary environmental effects from long-term storage of carbon dioxide (e.g., by deep-ocean injection).

In view of the costs associated with these policy options, the possibility that anthropogenic sources of greenhouse gases make no discernable impact on the normal variation in global climate must be examined. Alternative scenarios that an assessment could evaluate include: Would it make any real difference if no changes were imposed on the current trends in fossil-fuel use for transportation, industrial production, and space heating and cooling and on chemical production and use? What would happen if we do not reduce emissions as planned? There is, after all, the possibility that unforeseen feedback and other effects make the Earth resilient to anthropogenic perturbations. And even if there were discernible effects of global climate change, would the associated ecological risk be significantly greater than the risks from the multitude of other environmental problems?

With what certainty must we be able to answer the fundamental question of whether anthropogenic emissions affect global climate before climate-change-mitigation policies that incur significant societal costs can be decided? Adaptation strategies [i.e., actions designed to control or counteract

The Key Issues

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1. What position should the United States take in international negotiations about climate change (e.g., what constitutes "dangerous anthropogenic interference" with the climate system)?

2. Can Earth sustain or be resilient to the effects of anthropogenic perturbations?

3. Is the ecological risk from greenhouse gases significantly greater than that from other causes?

4. Are there any true "no regrets" options?

5. What happens if we do not reduce emissions as planned?

6. What is the level of domestic and international scientific and political consensus?

effects of global climate change (like rising sea level)] can be evaluated and debated in any case because their costs would not be incurred until the effects were obvious.

The weight of the scientific evidence accumulated has already instigated that debate. Nations are being forced to make decisions about natural resources, industries, and populations. Intertwined with concerns about biodiversity, urban air pollution, the socioeconomic effects of deferred industrialization, and international trade, global climate change is being assessed by national and international governmental bodies. The United States, historically the largest producer of carbon dioxide emissions, is a key player in this international policy arena. In international negotiations about what constitutes "dangerous anthropogenic interference" with the climate system, what position should the United States take?

Decision making may be influenced by the current political climate, the state of knowledge, and individuals' perspectives

7. Should the U.S. government take action on climate change; and if so, how?

8. Should the United States consider projections of global climate change in its resource-management practices (e.g., forests, water, agriculture, ecosystems, etc.)?

9. If the policy actions of the *Climate Change Action Plan* prove insufficient to meet the stated goals, how should the United States meet the year 2000 stabilization goal?

Public opinion should be taken into account in adopting any public-policy stance. No policy will be enforceable and effective if it does not carry the weight of public support and acceptance. Thus, the level of political as well as scientific consensus about global climate change should be assessed at domestic and international levels. If the populace exhibits severe doubts about the reality of a threat from climate change or if it shows widespread disagreement about the social and economic effects of policies designed to minimize or prevent climate change, then no policy is likely to be workable.

The most direct way to answer the questions and reduce the uncertainties about fossil-fuel burning and global climate change is to conduct scientific research and development. That R&D would be designed to probe the scientific aspects of global climate change and produce conceptual, bench-scale, and pilot-plant facilities for its abatement or mitigation. The basic research should indicate the reality of the situation and point to possible technological solutions. The development effort should explore methods for coping with the situation and altering the physical processes involved. At the same time, calls for action will still be heard, and policymakers will need to determine how R&D and actions should be balanced. The significance and implications of the research results will have to be continually assessed, and policy decisions justified by considerations from the technical, economic, social, and political spheres.

As policy options are weighed, another question must be considered: does the preponderance of scientific evidence indicate that policy should emphasize mitigation? Each of these policy routes carries a different mix of social, economic, and environmental costs. Choices will have to be made between low-cost quick fixes and more costly long-term solutions. And trade-offs will have to be made between environmental threats. For example, will it be better to lower carbon dioxide emissions from fossil-fuel-burning power plants at the cost of increasing the release of radioactive off-gases from nuclear power plants?

What Are the Implications of the Different Actions and Strategies?

Stated more directly, the question is, should the U.S. government take action on climate change; and if so, how? That question should be addressed over and over again as the scientific evidence is accumulated and analyzed, as political pressures build, and as different aspects of the problem come to light and are considered. For example, whether projections of global climate change should be taken into consideration in

forest management, utility development for cities, surface-water management, food-crop agriculture, and ecosystem management (e.g., for wetlands) will depend on the state of knowledge about climate-change effects at the time of planning, the location (i.e., different influences will be felt or perceived for the Everglades in Florida than for the forests of the Northwest), the planning horizon (long-term plans may be more sensitive to climate-change effects than short-term ones), and the levels of empowerment and political activism of the affected population among other influences.

Other questions arise as well: If any action is deemed necessary, to what degree should the efforts of federal, state, and local governments be coordinated? How should the private sector (e.g., major players like the electric utilities, natural-gas suppliers, the oil industry, the public and private transporation sectors, and heavy industry) be involved? Who will be involved in setting goals? And how open will be any debate of the means to achieve those goals?

There is no one answer to any of these questions. Indeed, these questions may never be explicitly asked or considered by the policy-making community. Rather, the questions will manifest themselves in a long series of small events and discussions: rate cases before public-utility commissions, management planning efforts of federal power producers, public-comment sessions on management plans for national parks, hearings on fuel-efficiency mandates to be set in legislations or federal-agency regulations, etc. Similarly, the question of whether there are any true "no-regrets" options may never be asked explicitly. Instead, it is quite possible that the business-as-usual scenario will simply be used as the baseline against which other options are measured in terms of costs and benefits.

The public and private leaders considering the issues and manifestations of global climate change might well ask themselves these questions:

- Are there domestic or international models or examples of cooperation that can be applied to the problem?
- Are there any opportunities for coordination with and learning from other countries' environmental policies?
- Is joint implementation a reasonable strategy to adopt for meeting commitments?

At the national level, a question is whether integrated assessment of global climate change must be international in context. The atmosphere does not circulate just within the borders of any one country. With any problem that is global in scope, the amount that one country can do alone is limited in comparison with what can be accomplished through international cooperation.

Any such cooperation would be marked by a number of characteristics:

- Extent: Will it entail discussions, exchange of data, provision of technology, coordinated economic planning, or financial aid?
- Subject scope: Will it cover energy use, fisheries exploitation, economic development, trade in forest products, trade in consumer goods,

10. Should the U.S. government use joint implementation to meet its commitments?

11. Are there models or examples of cooperation domestically and internationally that can be applied to the problem of global climate change?

12. What can the United States do alone, and what will require international cooperation?

13. What are the opportunities for coordination with and learning from other countries' environmental policies?

14. Must the integrated-assessment program for global climate change be international in context?

15. To what degree should or must the United States provide leadership to the international community?

population management, or urban and interurban transport systems?

- Enforcement mechanisms: Will it ensure compliance through favored trading status, tariffs, embargoes, or military intervention?

Such terms of cooperation would be subject to (in many cases, extensive) negotiations and constant review. And whether the United States, historically the world's largest producer of fossil-fuel emissions, should provide leadership to the international community would vary from situation to situation. On the one hand, the United States would have that leadership thrust upon it, given the advanced state of its technological capability and the broad infrastructure of its academic and scientific communities. On the other hand, the United States could study the lessons offered by other countries with long histories of dealing with specific environmental problems. The question of leadership would have to be decided on a case-by-case basis within the negotiations that will form the framework of policymaking and policy implementation.

Abatement and mitigation carry different mixes of social, economic, and environmental costs

Currently, the United States is committed to reducing its fossil-fuel emissions to their 1990 levels by the year 2000 under the terms of an agreement reached at the Earth Summit in Rio de Janeiro in 1992. Any assessment should be designed to evaluate the implications of meeting or not meeting that goal.

How Do We Integrate Climate-Change Issues with Other Social and Environmental Issues?

Climate change has joined a host of other aspects of international relationships. The relations among countries can be characterized and influenced by openness of trade, access to markets, accessibility to natural resources for exploitation, availability of intellectual resources, controls on information and communication, human rights accorded to citizens and foreign nationals, freedom to travel, and many other variables. Some of these variables are interdependent. For example, the ability to trade with a country is impeded if entry to the country is denied or travel within the country is restricted.

The inclusion of climate change as a variable in the calculus of international relations will rely on many of these variables (e.g., access to information about power production and fuel mixes) and will influence many of them (e.g., the trade in forest products may be curtailed as the trade in endangered species of wildlife has been). Indeed, climate change may affect U.S. international relationships, especially those with developing countries, in terms of aid, trade, infrastructure, and competitiveness.

The problem of characterizing global climate change is complicated by the concept of relative risk. Developing countries have many problems to deal with: population, disease, food supplies, poverty, drugs, civil disorder, po-

16. How does climate change affect U.S. relationships with developing countries in terms of aid, trade, infrastructure, competitiveness, etc.?

17. How do we coordinate global-climate-change issues with other important social and environmental issues?

18. Is integrated assessment even possible in the current institutional structure?

19. Understanding the relationship(s) among greenhouse-gas issues and other social and environmental issues (such as population) is very important.

20. How should climate policy be integrated with other policies?

21. How does federal policy on nongreenhouse issues affect carbon dioxide reduction?

22. The integrated assessment should address and incorporate broader (social and environmental) policy issues of the United States.

litical instability, regional air pollution, and others. These problems constitute competing demands for resources and attention. How do we trade off the actions required to deal with climate change with the actions needed to respond to these other problems? How do we integrate the responses to climate change with those aimed at these other pressing problems? How do we assign a relative risk to threats of such magnitude and to problems with such different immediacies?

Currently, we do not understand or fully appreciate the extent of interaction of climate-change policy with other aspects of international relations. We need to learn:

- What are the relationships among greenhouse-gas issues and other social and environmental issues, such as population?
- How can national policies on non-greenhouse issues affect carbon dioxide reduction?
- What equity issues will arise among countries affected, among sectors, and among regions?

Uncertainties about these issues call into question whether integrated assessment is even possible given the current state of our knowledge. Any integrated assessment of global climate change will have to address broad social and environmental policy issues of the United States, and the interactions among issues and initiatives will have to be contemplated, explored, and evaluated as climate-change policies evolve.

Who Are the Decision Makers?

If climate-change policies are to be coordinated at the local level, let alone the national or international level, then the specific decision makers need to be identified. This fact immediately raises the question, Who are the policymakers who deal with issues related to climate change? The answers range from the sublime to the inconceivable and can be exemplified by a series of cases:

At the household level, climate change can be affected by a choice of water heater. First, should the household use gas or electricity to heat its water? This decision might be influenced by the relative costs of operation. In the United States, information about energy use and efficiency is required on labels on major appliances. In addition to the cost of operation, the initial purchase cost may exercise a strong influence on the decision. Should the household buy a low-cost model that is not highly efficient or a higher-cost model that has a lower operating cost? Such decisions must be made every 10 to 15 years as the water heater has to be replaced. The initial water heater in the house may not have been selected by the user but by a previous owner or the contractor who built the dwelling. Neither of those purchasers would have a major stake in the long-term performance of the appliance and would be more influenced by its initial cost.

At the local-government level, waste-management practices can influence climate change. Should solid waste be incinerated (producing carbon dioxide and other environmentally active effluents) or landfilled (affecting groundwater quality, land use, and methane emissions to the atmosphere)? Such decisions are often made by municipal governments that are influenced by staff recommendations, national or regional regulations, property-owner objections, and many other influences. Paybacks from waste sorting and recycling may enter into the cost calculations as may the benefits of using waste as a fuel for power generation. In the

23. Who are the policymakers that care about climate change?

24. Specific decision makers need to be identified.

25. The integrated assessments themselves will help identify and inform the relevant policymakers and stakeholders.

long run, decisions about the market value of recycled materials, need for additional electricity-generating capacity, and the cost-effectiveness of producing electricity from waste may be made by utility engineers and executives, primary metals producers, trucking companies, and others.

And at the regional level, transportation policy may affect climate change. Should investments be made in mass transit? Should a highway system be constructed to support truck and car traffic? Should disincentives be established to limit personal-vehicle use, especially in urban areas? These types of decisions may be made at a variety of government levels or by a consortium of governments.

Climate change may affect international relationships in terms of aid, trade, infrastructure, and competitiveness

In all of these cases, the actual decision makers can be difficult to identify. In many cases, the ultimate decision is the result of many smaller decisions made sequentially by a variety of individuals and both formal and informal organizations. And in some circumstances, the decision maker can change from one instance to another.

Fortunately, the process of conducting an integrated assessment can help identify and inform the relevant policymakers and stakeholders. Public hearings can allow stakeholders to identify themselves and to make their opinions known. Meetings of regulatory bodies can bring together the responsible parties and force them to state their positions. Unfortunately, that statement of position may come before the presentation and evaluation of relevant information. As a result, an individual or an organization can commit to an ill-informed position. The assessment process should, therefore, strive to keep the debate open and the decision makers' positions flexible until the full weight of information and evidence can be considered.

26. Should government fund or provide incentives for R&D of "green technologies"?

27. How should the federal government direct its research to assist private, state, and local policy decision makers?

28. The scientific issues include investigations of the carbon cycle, general circulation model predictability, the ability to develop regional effects and impact studies, analyses of thresholds and discontinuities, and characterizations of uncertainties.

29. Documenting and communicating environmental change come down to measuring what we need and using what we measure; the amount of data produced in some of these environmental investigations is so massive that not all of it can be used, assimilated, or even accessed.

30. Many time scales are used in the study of global climate change; these scales are radically different from the time scales of biological growth and change. What time scales should we pay attention to?

What Directions Should Research Take?

Public and private research into the causes and effects of global climate change will be necessary if the problem is to be understood, if the policy debate is to be informed scientifically, and if the resultant policies are to win popular support and be effective. Because the federal government has been the major funder of climate-change research in the United States, it becomes the focus of research-policy questions. How should the federal government direct its research to assist private, state, and local policy decision makers? This question includes other queries, such as what research to pursue, how to balance research and development actions, and whether to provide incentives for R&D on "green technologies" that will eventually influence the marketplace and affect (lower) greenhouse emissions.

Topics of scientific research might include the carbon cycle, the predictive capabilities of general-circulation models, the ability to develop studies

of regional effects and impacts, analyses of thresholds and discontinuities, and characterizations of uncertainties. Prudence would dictate that studies also be conducted to identify the systems that are the most vulnerable to global climate change.

Once a fairly clear grasp of those fundamental climate-change issues is gained, more-specific (but still very broad in scope) questions can be approached:

- Can urban design and land-use policies be identified that would reduce carbon dioxide emissions and/or possible damages from climate change?
- What time scales should we pay attention to? Many time scales are used in the study of global climate change, from the diurnal cycle to the rate of glacial advance and retreat to the geologic time scale. These scales are radically different from the those of biological growth and change with which mankind must cope on a day-to-day basis.
- Documenting and communicating environmental change require measuring indicators of environmental quality over time and displaying the results of those measurements in ways that make any trends obvious. The amount of data produced in some of these environmental investigations is so massive that not all of it can be used, assimilated, or even accessed. Can we construct systems for gleaning the important data and processing it to form meaningful information?
- Given that a carbon-neutral economy is achievable at some date in the future, by how much can that date be advanced through R&D or other measures? Would the benefits gained be worth the cost of the investment?

A caveat to be heeded here: Research must be supported long enough to produce information that is reliable, demonstrable, and unambiguous. Research should not be terminated at an interim point at which incomplete results might lead to false conclusions.

Should We Pursue Mitigation or Adaptation?

In dealing with many problems, two extreme courses of action are (1) paying no attention to the causes and concentrating on withstanding the effects vs (2) ignoring the effects and concentrating on altering the root causes of the problem. A pragmatic approach might be to minimize the current effects while the root causes are determined and corrected. If such a pragmatic course is not followed, one extreme may be pitted against the other: "managing" the environment (e.g., building sea walls in response to rising sea level) against solving environmental problems (e.g., lowering the amounts of carbon dioxide released to the atmosphere by power plants). The kinds of decisions to be made regarding global climate change raise questions of mitigation (how would or could we reduce carbon dioxide emissions), adaptation (how could or should we alter the biological environment), and the level of information required to assess or even define some of these cases.

31. Research management must be supported long enough to really secure the "truth"; you do not want to make false conclusions at an interim point.

32. What systems are most vulnerable?

33. Is there a preponderance of evidence that policy should emphasize abatement/mitigation?

34. To what extent do existing government policies promote adaptation or response to global climate change?

35. "Managing" the environment vs solving environmental problems brings up questions of mitigation, adaptation, and the level of information required to assess or even define some of these scenarios.

One place to start in an integrated assessment of global climate change would be to ask to what extent existing government policies promote adaptation or active response to global climate change. Then the broader question could be addressed of whether the preponderance of evidence supports putting in place a policy that would emphasize abatement/mitigation or one that leans toward adaptation.

Research must be supported long enough to produce information that is reliable, demonstrable, and unambiguous

How Do We Deal with Uncertainty?

As in any broad-scale environmental assessment (or even everyday life), uncertainty is a major bedevilment of climate-change research. The changes that are to be identified and measured are very small in comparison with the interglacial, annual, diurnal, and even moment-to-moment changes that are regularly observed. Discerning a change in the integrated data is difficult and fraught with uncertainties that are intrinsic to the processes of physical measurement. Those uncertainties ideally would be reduced to the point that they are smaller than the change that is being measured so they will not mask that change. However, full understanding the phenomena involved or the reasons for change may not be achieved before decisions must be made.

36. What problems arise because of global-climate-change uncertainty; and how are industry and other private agents likely to behave under conditions of high uncertainty?

37. We must be able to have confidence in projections if they are to be used in policy decisions.

38. Projections must be developed in such a manner that the producers and users can place great confidence in them; those forecasts must demonstrate a credibility that justifies their use in policy decisions.

The condition is compounded because the climate system does not lend itself to laboratory experimentation. The scientific community is restricted to observing portions of the system and developing theories about its operation, theories that cannot be tested empirically and whose predictive applications are limited. However, those theories can be used to construct predictive models, particularly computer models. Because the observations on which the theories are based are so fractured, those models bring with them limitations and uncertainties of their own.

Today, those uncertainties limit (1) the conviction with which scientists can speak about global climate change and (2) the faith government and industry representatives are willing to place in climate-change analyses and predictions. With trillions of dollars involved in the debate (the costs of abatement or adaptation) and billions of lives at risk (the people supported by today's sources of crops, livestock, and seafood), decision makers must be able to have confidence in forecasts if they are to use those forecasts to drive policy decisions.

Yet because of today's global-climate-change uncertainty, we are not even sure what problems might arise. Not too long ago, sea-level rise from the melting of the polar ice caps was thought to menace Manhattan, Florida, and other low-lying coastal environs. Today, research suggests that that source of sea-level rise is not a major concern. However, similar research has found that thermal expansion of the seas from global warming may be a serious threat. With such new conclusions by the scientific community, heavy industries, power producers, insurance companies, and other private agents may be uncertain how to plan commitments of major resources. A major purpose of integrated assessment of global climate change would be to reduce such uncertainties.

How Do We Treat Risk?

The concept of economic risk is well established, and economic risk can easily be quantified in many cases. However, the concept of risk transcends economics. Any action that costs people money, status, or opportunity must be justified with certain benefits, such as compensation, reward, or the avoidance of a threat or risk. Without such benefits, the action and any underlying policy likely will falter. But risk is a relative matter. What is considered risk by one person might be considered downright fun by another. More to the point, what one person or group might perceive as a serious risk might be considered as just a minor risk by another constituency. This situation arises because the concepts of risk and danger are highly value-laden. People will consider something risky if it threatens something they value greatly: one's children or spouse, the family home, a job, a religious faith, freedom of movement, a right to own property, etc. Anything that would harm or do away with one of these valued entities would be perceived as a threat or risk that must be countered. Absent any perception of risk to a valued possession, action (which has its own risks as well as costs) would not be seen as desirable. Any assessment of global climate change should consider this concept of relative risk and should bear in mind that risk and danger are highly value-laden.

Issues associated with risk that might be investigated in global-climate-change integrated assessment include the following:

- How are the marginal costs of policy measures to be determined? That is to say, the economic costs may be fairly straightforward (it would cost *X* millions of dollars to construct a given facility), but the determination of other costs (loss of agricultural lands and jobs, uprooting from a family home, degradation of groundwater quality, loss of species, increase in noise level, etc.) may not be so easily costed.
- How is risk to be valued? Can we put a dollar value on a risk?
- Will perceived risk be considered the actual risk? A perceived risk might be entirely false, or it might be inflated by virtue of the value system used to assess the risk.
- How do private insurance markets and government insurance programs affect behavior and exposure to risk? Such systems are designed to reduce anxiety ("if something happens, I will be covered") and financial loss (a participating company will not go out of business if it suffers a disaster). However, some programs (such as storm-damage insurance for structures to be built along storm-prone coasts) seem to encourage self-destructive behavior.

The selection of alternative actions to be considered during the integrated-assessment process must therefore be based on an understanding of how the public perceives the risk, how the decision makers perceive the risk, and how the perception process operates. Moreover, the assessment of the selected alternatives must take into account not only the economic feedbacks that might be produced by the actions but also the likely psychological and social feedbacks.

39. How do private insurance markets and government insurance programs affect behavior and exposure to risk?

40. Integrated assessments should consider the concept of relative risk and should bear in mind that the concepts of risk and danger are highly value-laden.

41. The policy issues include the marginal cost of policy measures and the valuation of risk, both the risk perceived and that of extreme events.

42. The first highly visible manifestations of global climate change are likely to appear as extreme events (droughts, floods, hurricanes, tornadoes, etc.); therefore, the occurrence and effects of such extreme events might be analyzed and assessed.

How Do We Regard Extreme Events?

The first highly visible manifestations of global climate change are likely to appear as extreme events (droughts, floods, hurricanes, tornadoes, etc.). Therefore, the occurrence and effects of such extreme events might be analyzed and assessed. A major issue that must be faced by any such analysis is the weight to be assigned to extreme events:

- They might be discounted because, over a long period of time, they affect only a small portion of the population for only a short period.
- They may be considered shared risks of a population, as they are by an insurance pool. In such a case, the whole pool contributes to the cost of repairing the damage caused by the extreme event.
- They may be considered the design criteria that minimum actions must meet and control.

Global climate change is likely to appear first as a series of extreme events

Different stakeholders and decision makers might consider the same risk of an extreme event in different ways.

43. How should equity concerns be included in global-climate-change policy decisions?

44. Is heavy investment in emissions reduction or environmental-protection technologies a possible economic-trade bonanza?

45. Given that we can achieve a carbon-neutral economy at some date in the future, by how much can we advance the date through R&D or other measures, and what is it worth?

46. How will the distribution of costs and benefits affect key constituents, and what is politically feasible?

47. What equity issues will arise among countries impacted, among sectors, and among regions?

How Do We Assess the Costs and Benefits?

The potential costs of global climate change (the inundation of coastal areas, large agricultural regions rendered unsuitable to grow their traditional crops, disruption of the world's food supplies from farms and fisheries, loss of major foreign-exchange earners, shortages of forest products in the international marketplace, the undermining of important industries, worldwide inflation and unemployment, etc.) are staggering in monetary as well as human and ecological terms. The early discernment of any of these events (while the costs were still low) and the accurate prediction of their occurrence would be important in developing policies and support for counteractions.

Interpreting the costs of global climate change and the benefits of any countermeasures in understandable, concrete terms requires an assessment method. That assessment method not only will have to place values on costs and benefits but also will have to determine the distribution of costs and benefits to constituents. In a situation in which a powerful class of individuals is negatively affected while the disenfranchised are not affected, a call to action will most likely gain political momentum much more quickly than would occur for the inverse case.

That truism raises the issue of how equity concerns should be included in global-climate-change policy decisions. Among the questions raised by the workshop participants are:

- What equity issues will arise among affected countries, sectors, regions, and ethnic groups?
- How are less-developed countries to gain representation in the policy debate?
- Are the current mechanisms for promoting world peace and justice adequate to guarantee the rights of small and less-developed countries, or will new mechanisms be needed?

On the positive side, the heavy investment in emissions-reduction or environmental-protection technologies that might be required may constitute an economic boost and a major trade opportunity for the economies of the industrialized nations.

How Sensitive Must We Be to the Political Context?

Like a piece of a jigsaw puzzle, assessment should fill in the gaps between the neighboring pieces. Assessment should connect problems with solutions, questions with answers, and decision makers with potential actions. Assessment should contribute to the need, scope, type, and timing of action required. And to be effective, assessment should be targeted at a specific decision-making context.

Integrated assessments should never be conducted just to produce interesting scientific information. Rather, they should address real, focused policy issues, and they should be driven by these policy issues to provide the specific information needed to make an informed, rational, defensible response to some problem.

But scientific and technical information sometimes appears to be selectively used by policymakers. Why? Because cold, hard data do not alone drive decisions. Instead, other interests and commitments may determine the position of a decision maker. Many factors influence perceptions of reality in the political arena.

Politics and institutions matter. Scientists who think otherwise will sooner or later find their work unfunded. Assessors who think otherwise are likely to see their results unheeded. The decision process does not take place in a political vacuum. It takes place in a complex matrix of interests, favors, trade-offs, paybacks, loyalty, subterfuge, greed, altruism, honor, nobility, and self-interest. The motivations of decision makers vary.

Those conducting assessments should recognize that the issue they are involved in will be shaped and decided in the political arena. In that arena, the relative cost-effectiveness of measures (the "bang for the buck") will likely be an important determinant in accepting or rejecting an option. Therefore, this cost-effectiveness should be considered, analyzed, and presented in the assessment of any potential action.

What Is the Fundamental Nature of Integrated Assessment?

Integrated assessment is not a report or other document produced by an individual, institution, consortium, or committee. It is an evolving process during which problems are identified, solutions are proposed, questions are raised, answers are sought, and learning takes place. To make sure that all of these activities occur, the assessment process should emphasize communication, ensure that a continuing dialogue develops among the partici-

48. Scientific and technical information is selectively used by policymakers. Why?

49. Assessments need to be targeted at specific decisionmaking contexts.

50. Integrated assessments should contribute to the need, scope, type, and timing of the action needed.

51. Integrated assessments should never be conducted just to produce interesting scientific information. They must address real, focused policy issues, and they should be driven by these policy issues to provide the specific information needed to make an informed, rational, defensible response to some problem.

52. In the political arena, the relative cost-effectiveness of measures will be an important determinant in the acceptance or rejection of integrated-assessment results. Therefore, cost-effectiveness should be considered in the assessment of any potential action.

53. Politics and institutions matter. Process does not take place in a political vacuum; motivations vary.

pants, and make sure that research findings are archived. In addition, the assessment process needs to be flexible, timely, iterative, and transparent. It should involve all affected parties (interest groups, critics, and the customer/decision maker), and it should include outreach and evaluation.

The growing amount of literature on assessment indicates that, to be truly integrated, an assessment depends on

- Finding and including people who can step across institutional boundaries, use the strengths and avoid the biases of each participant, and communicate across the gap between theoreticians and lay people and
- Identifying and informing the relevant policymakers and stakeholders in the course of the assessment process.

However, the identification of policy issues and of the consequences of alternative policy responses to these issues is rarely a simple, straightforward activity. Broader assessments (e.g., those of the IPCC) should usually be an iterative and interactive process involving scientists, the public, and decision makers. The specific policy options used to develop a particular assessment are inherently unpredictable. Because of this unpredictability, assessments necessarily take on an entrepreneurial aspect.

At the very outset, the policy issues to be investigated should be expressed specifically, and the core information requirements must be identified and defined. As the assessment progresses, it should include at least five basic components: foundation building, a general assessment, tool construction, common databases, and a directed or focused assessment.

This taxonomy makes it sound as though the assessment process is a very linear, single-minded process. It is not.

54. Integrated assessments should emphasize communication and ensure that a continuing dialogue develops and archives are provided for research findings.

55. To get usable assessments, decision makers must express policy issues in a specific manner.

56. The policymaker should not be boxed in. Assessments should evaluate the consequences of decisions, not make recommendations.

57. The integrated-assessment process should be flexible, timely, iterative, and transparent. It should involve all affected parties (interest groups, critics, the customer/decision maker), outreach, and evaluation.

58. The identification of policy issues and alternative responses to those issues is rarely a simple, straightforward activity. Instead, it is usually an iterative and interactive process involving scientists, the public, and decision makers.

59. Specific policy options that would be used to guide assessments are inherently unpredictable. Therefore, integrated assessments are necessarily entrepreneurial.

60. The core information requirements need to be defined.

61. Integrated assessments should use multiple approaches to develop a consensus among stakeholders about the direction, magnitude, and uncertainties of the societal and ecological effects of a decision that can and must be made.

62. Any integrated assessment should include at least five basic components: foundation building, a general assessment, tool construction, common databases, and a directed or focused assessment.

63. Integrated assessment may comprise a series of subassessments, each of which is targeted at a specific problem, approach, information need, or concern.

64. Broader (i.e., IPCC-type) assessments should be linked to targeted assessments for purposes of definition and delineation. In particular, feedbacks from the broad assessments to the targeted assessments are necessary.

65. A process of continuous foundation building coupled with periodic policy-driven integrated assessments is required.

66. The successful integrated assessment will find and include people who can step across institutional boundaries, use the strengths and avoid the biases of each, and communicate across the gap between theoreticians and lay people.

Assessments typically use multiple approaches to develop a consensus among stakeholders about the direction, magnitude, and uncertainties of the societal and ecological effects of a decision that can and must be made. And although assessments are devoted to understanding and helping to resolve a particular problem, that problem is rarely simple. So the assessment is broken up into a series of subassessments, each of which is targeted at a specific part of the problem, an approach, an information need, or a concern. Broader (i.e., IPCC-type) assessments should be linked to these targeted subassessments for purposes of definition and delineation, and feedbacks from the broad assessments to the targeted assessments are necessary.

Some guidelines and caveats for assessors that emerged from the workshop follow:

- Seek a process of continuous foundation building coupled with periodic policy-driven assessments.
- Do not box the policymaker in; allow some flexibility for negotiations, give and take, and tradeoffs among the various interests coming to bear on the issue and the policymaker(s).
- Evaluate the consequences of decisions; do not make recommendations.
- Develop projections that all parties can understand and can have confidence in.

What Directions Should Development Take?

Currently, the most pressing need of the scientific community in the conduct of integrated assessments is the development of generic tools to evaluate four classes of policy intervention:

- Information provision
- Research and development
- Regulation
- Incentives

To support policy decisions, an assessment should describe the environmental and socioeconomic drivers and consequences of each action contemplated. Funding agencies need to make a range of investments to ensure that the appropriate tools and capabilities are available to address specific questions as they arise.

Must We Seek a General Understanding of the Underlying Physical Phenomena?

Assessing the implications of proposed mitigation or adaptation options raises questions of the level of information required to properly assess or even define them. For example, for the proposed option of deep-sea injection of carbon dioxide, detailed information would be needed about the physical chemistry of carbon dioxide hydrates at high pressures and low temperature and on the biological effects of carbon dioxide hydrates on an ecosystem that has barely been observed, let alone studied.

67. How should R&D and actions be balanced?

68. How can urban design and land-use policies be constructed to reduce carbon dioxide emissions and/or possible damages from climate change?

69. Generic tools are needed to evaluate four classes of policy intervention: R&D, regulation, incentives, and information provision.

70. Physical measurements that document change have intrinsic uncertainties or errors, so the change that is being measured has to be larger than those uncertainties. Understanding phenomena or reasons for change is crucial for offering solutions.

71. Funding agencies need to make a range of investments to ensure that the appropriate tools and capabilities are available to address specific questions as they arise.

72. The environmental and socioeconomic drivers and consequences are the most pressing development needs for integrated assessments' support of policy decisions.

73. The USGCRP resources need to be prioritized. (There is little support for general information.)

Such fundamental research and understanding would be needed to avoid creating new, and perhaps more dangerous, problems. An example of such a case is the disposal of hazardous wastes. Prior to the sixties, such wastes were commonly disposed of by burial. That practice was considered to provide a physical separation and protection from the hazards of the wastes. However, migration and groundwater contamination were not understood and factored into the assessments of the hazards. Today we have a legacy of soil and groundwater pollution that is much more difficult and expensive to deal with than was the original problem. A fundamental understanding of the physical and biological processes involved may have avoided this extra danger and expense. So, too, should the fundamental processes of any action proposed for dealing with the causes of of global climate change be investigated and understood.

Economic development is both a cause of and a solution to global warming.

74. The social and economic issues include developing country industrialization (how technology would penetrate those countries and how those countries fit into the world economy), development policy, food supply, public health, and interest groups (how they are going to be affected).

75. Economic development is both a cause of and solution to global warming, increasing resource consumption and energy emissions while tending to decrease traditional practices and population growth.

76. The assessment of global climate change will require the evaluation of human behavior and responses (e.g., risk perception, communicative behavior, attitudes, and preferences).

77. Population has a tremendous impact on global change, and efforts to control population involve making a number of decisions about, for example, education, birth control, or intervention.

What Social Phenomena Must Be Understood?

In less-developed and developed societies alike, the assessment of global climate change will require the evaluation of a wide range of human behaviors and responses, such as risk perception, communicative behavior, attitudes, and preferences. The uncertainties associated with data and models dealing with such social phenomena, however, can be as great as or greater than those associated with physical or biological systems.

Social and economic issues that should be studied, understood, and factored into an integrated assessment include

- The industrialization of developing countries (how technology would penetrate those countries and how those countries fit into the world economy)
- Development policy
- Food supply
- Public health
- Education and literacy and their role in industrialization
- The formation, leadership, and effective actions of interest groups (how they are going to be affected)
- Population, which has a tremendous impact on global change (efforts to control population involve making a number of decisions about, for example, education, birth control, or intervention)

It should be noted that economic development is both a cause of and a solution to global warming. Development tends to increase resource consumption and energy emissions. At the same time, it tends to decrease traditional practices (e.g., gathering firewood from forests, thereby degrading the biomass potential of those forests) and to slow population growth [lessening the potential pressures on the food supply, urban and rural land, (un)employment levels, the urban infrastructure, and social services].

Conclusions

At the end of the workshop, the steering committee, whose membership reflected the diversity of the full group, reviewed and analyzed the issues raised by the breakout groups to identify common concerns and areas of specific significance. That committee identified five basic themes within the discussions of the breakout groups:

Process Counts

The most important aspect of assessment is the process of communication, review, stakeholder involvement, broadening of perspectives, balancing of needs, bartering of support, discovery of common goals, gradual understanding, and evolutionary resolution that can occur; assessment is not simply a report.

Multiple Approaches Are Needed

The assessment process must use a variety of approaches with fundamentally different assumptions, with a wide range in focus, and with various levels of analytical sophistication (from back-of-the-envelope calculations to different kinds of end-to-end modeling). Scenario effects across a range of indicators need to be compared, augmenting cost/benefit analyses.

Effects Dominate

Perceived ecological, social, and economic consequences of global climate change will determine the most pressing need for integrated assessment in support of policy decisions. Extreme events (droughts, floods, hurricanes, etc.) must be included in the assessment because of their high visibility and critical effects on systems.

Context Is Important

The assessment process and its results must be viewed in the context of the policy issues at hand, the broader social and environmental policy issues facing the United States, the availability of information, and the experience and background of the stakeholders and decision makers. The process necessarily will be iterative and will use different approaches as it evolves. A key to success will be hiring people who can step across organizational and disciplinary boundaries to provide lines of communication among the decision makers, stakeholders, and scientist/assessors.

Uncertainty Must Be Characterized

The assessment process must allow all participants to develop confidence in the process and to appreciate the uncertainty inherent in its outcomes. Uncertainty must be considered in a meaningful way and clearly communicated to lay audiences.

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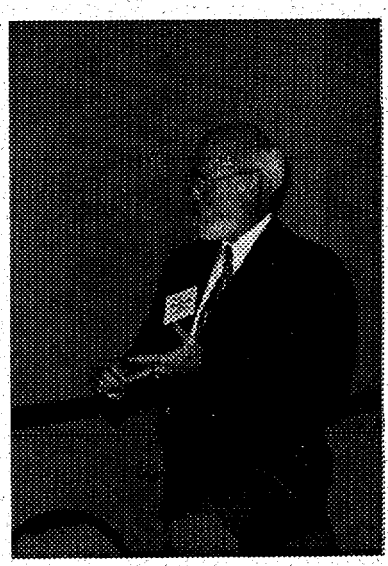

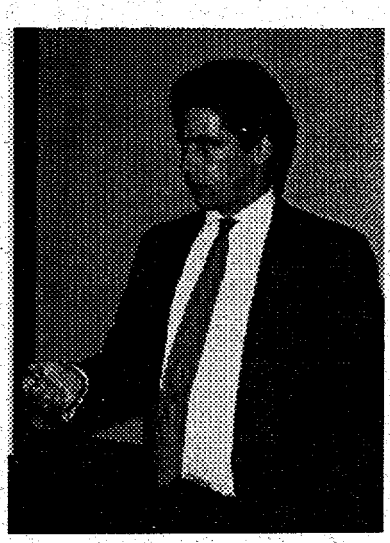

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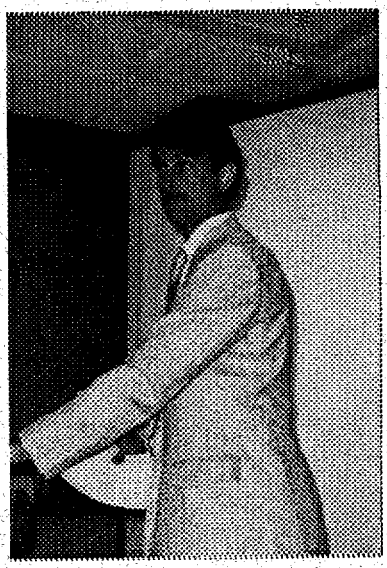

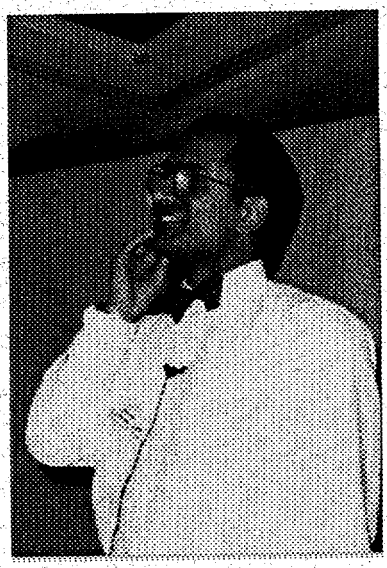

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