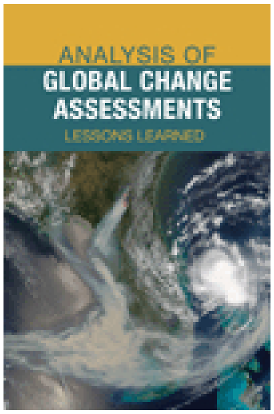

Analysis of Global Change Assessments: Lessons Learned

Committee on Analysis of Global Change Assessments, National Research Council

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ANALYSIS OF GLOBAL CHANGE ASSESSMENTS

LESSONS LEARNED

Committee on Analysis of Global Change Assessments

Board on Atmospheric Sciences and Climate

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Preface

Communication between scientists and decision makers has always been a challenge. The two communities use different languages and have different needs. Before scientists can convey their information, which usually appears in the peer-reviewed literature, to decision makers, it needs to be synthesized and integrated so that relevant facts can be communicated in a useful form. Assessments are evaluation and consensus building processes for establishing an integrated view of recent scientific breakthroughs and providing policy-relevant information to decision makers. For assessments to be effective and credible, the process has to be open and must provide accurate, useful, and scientifically tested information.

During the last four decades, many assessments have been produced to address important questions related to environmental issues such as ozone depletion, climate change, and the loss of biodiversity. Many of these assessments have been conducted at the international level and have provided the scientific basis for the elaboration of international agreements such as the Montreal Protocol on Substances that Deplete the Ozone Layer (1987), the United Nations Framework Convention on Climate Change (1992), and the Kyoto Protocol to the United Nations Framework Convention on Climate Change (1997). They gave scientists the opportunity to develop networks of expertise and to provide the latest information to policy makers in many countries. Assessments have become a common activity, but their success depends on a number of conditions. This report analyzes conditions that contribute to successful assessments.

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In the United States, the first national assessment focused specifically on climate change was conducted under the auspices of the U.S. Global Change Research Program and completed in October 2000. A second round of assessment was initiated in 2002 by the U.S. Climate Change Science Program (CCSP). Recently, the research community and the CCSP leadership agreed that it would be valuable to evaluate the assessment process itself to learn from various past efforts in conducting assessments with the goal of guiding future assessment activities. Therefore, in the spring of 2004 the CCSP asked the National Academies to look at lessons learned from past global change assessments (see Appendix A for the Statement of Task). In response, an ad hoc committee of 12 members was formed (see Appendix E for the committee's composition and biographies). The committee was charged with undertaking a comparative analysis of past global change assessments with goals similar to the CCSP to identify strengths and weaknesses in the process. Based on that analysis, the committee was asked to provide CCSP with advice on its approach to future assessment activities.

The committee held five meetings to gather information and deliberate on its findings and recommendations. During the first meeting, the committee met with CCSP representatives to discuss the committee's charge and with scholars to learn from past evaluations of global change assessments. At its second meeting, additional scholars were consulted for their analysis of assessment processes. In addition, renowned leaders of assessment processes were invited to reflect on the strengths and weaknesses of the processes in which they were involved. Stakeholders from the private sector and from regional to federal government were invited to the third and fourth meetings to discuss design issues that could foster effective engagement of user communities and ensure that assessments meet the needs of the target audience. As an example of an international approach, the committee heard from German scientists about their global change assessment processes during its fourth meeting. The final meeting was reserved for closed committee deliberation and report development.

I would like to thank all of the individuals who shared their knowledge and experience with members of our committee and assisted us in gathering the information needed to formulate sound recommendations. The committee is to be complemented for its diligence and commitment to this study. I thank, in particular, the vice-chair Katharine L. Jacobs, who assisted me in organizing the work of the committee and in chairing some of the sessions.

It is also a pleasure to recognize the outstanding work of the study director, Dr. Claudia Mengelt, who did a superb job in the conduct of the present study and was assisted very effectively by senior program assistant Rachael Shiflett at the National Research Council.

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The committee hopes that this report will be useful to the CCSP in identifying lessons learned from past assessments and in providing advice to guide future global change assessment activities in the United States.

Guy P. Brasseur
Chair

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Acknowledgments

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Patricia Anderson, University of Alaska, Fairbanks
Scott Barrett, Johns Hopkins University, Washington, D.C.
Ann Bostrom, Georgia Institute of Technology, Atlanta
William C. Clark, Harvard University, Cambridge, Massachusetts
Brian Flannery, Exxon Mobil Corporation, Clinton, New Jersey
Gerald Galloway, University of Maryland, College Park
Henry Jacoby, Massachusetts Institute of Technology, Cambridge, Massachusetts
Jennifer Logan, Harvard University, Cambridge, Massachusetts
Michael C. MacCracken, Climate Institute, Washington, D.C.
M. Granger Morgan, Carnegie Mellon University, Pittsburgh, Pennsylvania
Roger Pulwarty, NOAA-CIRES Climate Diagnostics Center, Boulder, Colorado

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Although the reviewers listed above have provided constructive comments and suggestions, they were not asked to endorse the report's conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Thomas Graedel, Yale University, and Debra Knopman, The RAND Corporation; appointed by the National Research Council, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

The committee would also like to thank the many individuals who contributed during the committee's information gathering phase especially: Stephen O. Anderson, U.S. Environmental Protection Agency; Dan Basketfield, Senior Water Resources Engineer, Seattle Public Utilities; Tom Buschatzke, Water Advisor, City of Phoenix; William Clark, Harvard University; Robert Corell, National Science Foundation, retired; William Fang, Edison Electric Institute; John H. Gibbons, Resource Strategies; Hartmut Grassl, University of Hamburg, Germany; Bryan Hannegan, formerly Council on Environmental Quality; Tony Janetos, Joint Global Change Research Institute; Jim Jensen, National Academies; James Mahoney, National Oceanic and Atmospheric Administration, retired; Susi Moser, National Center for Atmospheric Research; Walt Reid, Packard Foundation; Sam Sadler, Oregon Department of Energy; John Schellnhuber, Potsdam Institute für Klima, Germany; Peter Schultz, Climate Change Science Program; Truman Semans, Pew Center; Margaret Spring, U.S. Senate staff; Stacy VanDeveer, University of New Hampshire; Bob Watson, World Bank; and Thomas Wilbanks, Oak Ridge National Laboratory.

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Summary

An assessment process is a key interface between science and policy and a crucial mechanism by which science informs policy making. It can establish the importance of an issue, provide an authoritative resolution of policy-relevant scientific questions, demonstrate the benefits of policy options, identify new research directions, and provide technical solutions. As a result of an increasing number of international treaties and national mandates, the number of global change assessments, as well as the resources and the number of scientists dedicated to such assessment activities, is growing. At the same time, a wealth of experience on how to conduct assessments has accumulated. Given the continuing need for assessment activities in the future, it is an opportune time to systematically evaluate the approach and effectiveness of past assessments and learn from the available experience.

In the United States, the Global Change Research Act (GCRA) of 1990 mandates that every four years an assessment be conducted of the impacts of global change on eight areas: the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity. Responding to this mandate, the National Assessment of Climate Change Impacts (NACCI) was carried out during the late 1990s, and a second assessment activity, comprising 21 synthesis and assessment products within the U.S. Climate Change Science Program (CCSP), is currently under way. Given the GCRA's mandate to provide such assessment efforts at a regular interval, assessment

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leaders and practitioners recognized the value in learning from these and other assessment processes to improve future efforts.

Against this background, the CCSP, which coordinates U.S. climate and global change research conducted at 13 government agencies and is responsible for conducting global change assessments for the United States, asked the National Academies to identify lessons learned from relevant past global change assessments at both national and international levels as a guide for future assessment activities. An ad hoc committee, composed of individuals who have studied, participated in, or been users of global change assessments, was convened to prepare this report. To inform its deliberations, the committee met with scholars who have evaluated or participated in assessments, with leaders of past assessments, and with users of assessments. For the report's conclusions, the committee draws both from existing literature and from its examination of a relatively small but varied selection of global change assessments (Table S.1), each analyzing global change processes that are at least in part driven by human activities. The committee's recommendations provide general guidance for those who conduct assessments and also, where appropriate, identify specific issues relevant to future CCSP assessment activities.

TABLE S.1 The Eight Examples of Assessment Processes Included in the Comparative Analysis

Assessment	Brief Description
Stratospheric Ozone Assessments	Prior to the 1987 Montreal Protocol, there were several national (including NRC) and international assessments analyzing ozone-depleting chemicals and the state of the stratospheric ozone layer (WMO 1982, 1986). Following the treaty, a system of expert advisory panels was established to periodically assess the atmospheric science of the ozone layer (WMO 1990a, 1990b, 1992, 1995, 1999, 2003, 2007), the impacts of ozone loss (UNEP 1991a, 1994a, 1998a, 2002a), and the technology and economics of alternatives to ozone-depleting chemicals (UNEP 1991b, 1994b, 1998b, 2002b).
Intergovernmental Panel on Climate Change (IPCC)	IPCC analyzes scientific and socioeconomic information on climate change and its impacts, and assesses options for mitigation and adaptation. It provides scientific, technological, and socioeconomic findings to the Conference of the Parties to the United Nations Framework Convention on Climate Change (IPCC 1990a,b,c, 1995a,b,c, 2001a,b,c).
Global Biodiversity Assessment (GBA)	GBA provides a synthesis and analysis of available science on biodiversity to support the work of the UN Convention on Biological Diversity (GBA 1995).

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TABLE S.1 Continued

Assessment	Brief Description
National Assessment of Climate Change Impacts (NACCI)	NACCI was undertaken in response to the Global Change Research Act (1990) to evaluate the impacts of climate change on the United States (NAST 2001).
Arctic Climate Impact Assessment (ACIA)	Primary objectives were to evaluate and synthesize knowledge and indicators of climate variability, climate change, and ultraviolet radiation in the region; to assess possible impacts of future changes in climate and radiation; and to provide reliable information to both governments and peoples of the region to support policy-making processes (ACIA 2004).
Millennium Ecosystem Assessment (MA)	MA was designed to answer questions fundamental to various UN conventions dealing with natural resource issues, in particular the consequences of diverse environmental changes on the functioning of ecosystems, including their continuing capacity to deliver services essential to human well-being (MA 2005a,b).
German Enquete Kommission on "Preventive Measures to Protect the Earth's Atmosphere"	The Enquete Kommission brings scientists and policy makers together to assess, in this case, the importance and consequences of stratospheric ozone depletion and climate change for Germany among other dimensions of global environmental change (Enquete Kommission 1988, 1991).
Synthesis and Assessment Products by the U.S. Climate Change Science Program (CCSP)	The 21 assessment products are designed to address the mandate of the Global Change Research Act by considering science and policy issues spanning the range of topics addressed by the CCSP. The first product, on temperature trends in the lower atmosphere, was released in April 2006 (CCSP 2006).

ESSENTIAL ELEMENTS OF EFFECTIVE ASSESSMENTS

Certain strengths and weaknesses, common to several assessments analyzed by the committee, illuminate critical features of effective assessments. For example, a well-defined mandate and consistent support from the requesters of the assessment contributed importantly to the effectiveness of the Arctic Climate Impact Assessment (ACIA) and the stratospheric ozone assessments, while the process outcome of the Global Biodiversity Assessment (GBA) was impaired by lack of a clear mandate from the target audience. Several assessments benefited significantly from well-articulated, multifaceted, and extensive communication strategies. The ozone assessments were especially effective in providing relevant information for decision-making processes,

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whereas the ACIA was outstanding in the scope of its communications outreach. Other components of effective assessments included superior leadership, extensive and well-designed stakeholder engagement, and a transparent and effective science-policy interface. Perhaps the most common weakness of past assessments has been a discrepancy between the scope of the mandate and the funding provided for the assessment effort.

Drawing both on this comparative analysis and on relevant literature, the committee identified 11 essential elements of effective assessments:

1. A clear strategic framing of the assessment process, including a well-articulated mandate, realistic goals consistent with the needs of decision makers, and a detailed implementation plan.
2. Adequate funding that is both commensurate with the mandate and effectively managed to ensure an efficient assessment process.
3. A balance between the benefits of a particular assessment and the opportunity costs (e.g., commitments of time and effort) to the scientific community.
4. A timeline consistent with assessment objectives, the state of the underlying knowledge base, the resources available, and the needs of decision makers.
5. Engagement and commitment of interested and affected parties, with a transparent science-policy interface and effective communication throughout the process.
6. Strong leadership and an organizational structure in which responsibilities are well articulated.
7. Careful design of interdisciplinary efforts to ensure integration, with specific reference to the assessment's purpose, users needs, and available resources.
8. Realistic and credible treatment of uncertainties.
9. An independent review process monitored by a balanced panel of review editors.
10. Maximizing the benefits of the assessment by developing tools to support use of assessment results in decision making at differing geographic scales and decision levels.
11. Use of a nested assessment approach, when appropriate, using analysis of large-scale trends and identification of priority issues as the context for focused, smaller-scale impacts and response assessments at the regional or local level.

The committee concludes that attention to these elements, many of which have been identified in the existing literature, increases the probability that an assessment will be credible, legitimate, and salient (see Box S.1), and therefore will effectively inform both decision makers and other target

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BOX S.1
Definitions of Key Terms

Three essential properties of a successful assessment process:

- *Salience* relates to an assessment's ability to communicate with the users whose decisions it seeks to inform and whether the information is perceived as relevant.
- *Credibility* addresses the technical quality of information, as perceived by the relevant scientific or other expert communities.
- *Legitimacy* concerns the fairness and impartiality of an assessment process, as judged by its users and stakeholders.

Global Change Assessments: Global change assessments are collective, deliberative processes by which experts review, analyze, and synthesize scientific knowledge in response to users' information needs relevant to key questions, uncertainties or decisions.

Stakeholders: Stakeholders in the assessment process are defined as all interested and affected parties.

Target Audience: Target audience refers to the potential users of assessments. Often, the primary target audience consists of federal government officials who are responsible for the decisions the assessment is intended to inform. However, the target audience may also include state and municipal governments, private-sector users, the public, or intermediaries who function as science translators to decision makers (e.g., media, congressional staff, business associations, environmental organizations).

SOURCES: NRC 1996, Social Learning Group 2001a, Clark and Majone 1985, and Ravetz 1971.

audiences. In the full set of findings and recommendations presented in Chapter 5, the committee provides guidance for incorporating these elements into future assessments. In this summary, the committee highlights some especially challenging aspects of assessment processes and emerging approaches. These challenges include effectively framing assessments, engaging stakeholders, weighing the benefits of assessments against their opportunity costs, employing nested assessment strategies, and developing decision-support tools.

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FRAMING THE ASSESSMENT

A well-formulated mandate is required to ensure that the assessment process is demand-driven and effectively supports a particular set of decisions. As part of the mandate, goals and objectives need to be clearly articulated, including the kinds of decisions that the assessment should inform, how the assessment will be implemented, and how progress towards goals will be measured. The assessment's mandate and goals should be agreed upon in advance by those requesting the assessment and the assessment leaders, and should only be modified during the assessment through a transparent process. In addition, the respective roles of those requesting and those funding the assessment in the scoping process should be clarified in the original guidance document to avoid major discrepancies between the assessment's mandate, expected results, and available funding. A detailed guidance document specifying those terms of the assessment process will also increase both legitimacy and salience.

Recommendation: The leadership of and those requesting assessments should develop a guidance document that provides a clear strategic framework, including a well-articulated mandate and a detailed implementation plan realistically linked to budgetary requirements. The guidance document should specify decisions the assessment intends to inform; the assessment's scope, timing, priorities, target audiences, leadership, communication strategy, funding, and the degree of interdisciplinary integration; and measures of success.

Although CCSP has a mandate under GCRA to conduct assessments, the program lacks a long-term strategic framework for meeting this mandate. Prior to undertaking future assessments, CCSP should clearly express program goals in addition to goals for each assessment, specifying decisions the program intends to inform. A strategic plan comprising overall goals, mandate, and implementation strategy for CCSP assessment activities would enhance the salience, credibility, and legitimacy of future assessments—especially if the plan is accepted at high levels of government as well as within the science agencies and the scientific community. Such an overarching long-term strategic plan for CCSP assessment activities would foster programmatic and funding continuity that could adapt to evolving circumstances and changes in political administration.

Recommendation: The CCSP should develop a broad strategic plan for its assessment activities that focuses not only on specific short-term objectives such as preparing the next report or assessment product, but also on longer-term objectives that are in the national interest.

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BALANCING ASSESSMENT BENEFITS WITH OPPORTUNITY COSTS

Assessments provide obvious benefits to society by applying sound science to the decision-making process. The research community also benefits from assessments in multiple ways, including establishing the state of knowledge bringing together disciplines that are often isolated, resulting in new lines of investigation and creating new interdisciplinary fields. However, assessments also involve opportunity costs. With an ever-growing number of scientists involved in an increasing number of assessments, time and resources are diverted away from producing new research results. Other unintended consequences include a decreased ability to recruit a balanced pool of high-quality assessment participants and volunteer reviewers, and the diminished impact of an individual assessment if target audiences are overwhelmed with the sheer volume of information from assessments.

Given the important contributions of assessments to policy making and to society in general and the growing number of international treaties and national mandates, efficiency considerations become increasingly important to minimize the opportunity cost to the research community. New approaches to assessments might minimize such costs. For example, assessments that are scheduled at regular intervals (such as IPCC and those mandated by the GCRA) could limit their scope to examining only significant new developments and providing succinct summaries of the previous state of knowledge. Thus, each report would build on, rather than duplicate, previous efforts. In addition, assessments conducted at different scales (global, national, or regional) could be nested and run in phases to optimize the ability to build on previous assessments. Similarly, assessments that seek consensus on the underlying science could be phased such that they are completed in time to inform impacts and response assessments.

Recommendation: Care is required to make sure the burden of assessments on the scientific community is proportional to the aggregate public benefits provided by the assessment. Alternative modes of participation or changes to the assessment process—such as limiting material in regularly scheduled assessments or running "nested" or phased multiscale assessments—should be considered. As appropriate, U.S. assessments should acknowledge the work of the international community and avoid redundant efforts.

IDENTIFYING, ENGAGING, AND RESPONDING TO STAKEHOLDERS

The assessment community has recognized the importance of broad engagement of stakeholders—including those who request and fund an

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assessment, experts who participate in the assessment process, and the target audiences or users of the assessment—in order to ensure salience and legitimacy. Effective stakeholder engagement requires identifying and addressing the needs of specific target audiences, establishing appropriate boundaries at the science-policy interface, engaging stakeholders beyond the target audience, building the capacity of stakeholders to engage in assessments, and a comprehensive, multifaceted communication strategy. Meeting this objective may require significant resources and may thus need to be balanced with efficiency considerations. However, the importance of stakeholder engagement to the overall success of an assessment implies that budgetary provisions, especially for communication, should reflect this reality.

Defining and responding to the needs of the target audience is a critical component of an effective assessment process, requiring a continual dialogue between scientists and the target audience. Involvement of the target audience will also promote legitimacy and ownership of the process. The target audience may also comprise intermediaries, such as media, non-governmental organizations, professional organizations, business associations, or "science translators" such as policy advisers and congressional staff members. Because engagement of target audiences in the policy arena is resource intensive and may require expert facilitation, both human and financial resources for such activities should be identified early in the process.

Recommendation: The intended audiences for an assessment should be identified in advance, along with their information needs and the level of specificity required for assessment products to be most salient and useful. In most cases, the target audience should be engaged in formulating questions to be addressed throughout the process, in order to ensure that assessments are responsive to changing information needs. Both human and financial resources should be adequate for communicating assessment products to relevant audiences.

Defining an appropriate interface between the assessment process and the policy makers who requested and pay for it is a critical challenge in assessment design. Although a deliberate and transparent boundary is necessary to avoid the perception of interference in scientific conclusions, a continuous dialogue is also needed to ensure that questions deemed most relevant by the decision makers are addressed. Perceptions about the degree of government influence can diminish the value of an assessment in the eyes of many stakeholders. Such perceptions may be difficult to overcome, making it especially important to establish guidelines that will stand the test of time.

CCSP's assessment activities have raised credibility and legitimacy issues with some stakeholders, particularly in the science community, due

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to the way the boundary between science and policy was designed. For example, each assessment product is reviewed by the government and requires approval by high-level government officials, raising the question of whether the users of the assessments not only control the questions being asked but, at least potentially, also the scientific conclusions. This concern is addressed to some extent by posting both pre- and post-review versions of each report to allow tracking of the changes. Nonetheless, there remains skepticism about the degree to which government influence may affect scientific outcomes, not only through funding but also through review of final products.

Recommendation: The leadership of and those requesting the assessment should establish a transparent and deliberate interface between participants and those who request or sponsor the assessment. Clear guidelines and boundaries should ensure both salience to those requesting the assessment and legitimacy, especially with respect to the perceived influence of those requesting the assessment might have over the scientific conclusions drawn.

Despite general understanding that broad stakeholder engagement can contribute importantly to a successful assessment, how to identify and engage the appropriate stakeholders is not self-evident. Participation by broad audiences throughout the assessment process may increase legitimacy and salience, but it could also weaken the credibility of the process. In addition, involvement of too many stakeholders could make the assessment process inefficient and too costly. The appropriate balance between broad stakeholder engagement to achieve legitimacy and salience, and the need to achieve efficient and credible outcomes, will depend on the specific context of each assessment and requires careful consideration early in the assessment design process.

Recommendation: A strategy for identifying and engaging appropriate stakeholders should be included in the assessment design to balance the advantages of broad participation with efficiency and credibility of the process.

Capacity building to develop a common language and technical understanding among assessment participants, users, and stakeholders can greatly enhance the potential for effective assessments. When stakeholders are unfamiliar with the science or the policy context of a given assessment, their ability to engage in the process will be limited. Investments in capacity building can have payoffs in multiple areas, including: (1) expanding the informed audience for assessments, (2) contributing to future assessment

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effectiveness, (3) expanding the ability of decision makers to act on scientific information, (4) equipping participants with new knowledge on assessment methodology and tools, and (5) building a scientific community that is more sensitive to needs and concerns of the broader society.

Recommendation: Capacity building efforts for diverse stakeholders and assessment participants from various disciplines should be undertaken by CCSP in order to develop a common language and a mutual understanding of the science and the decision-making context. This capacity building may be required to ensure the most salient questions are being addressed and to meaningfully engage diverse stakeholders in assessment activities.

DEVELOPING DECISION-SUPPORT APPLICATIONS

Decision-support applications include a wide range of tools and models that link analyses, environmental and social data, and information about decisions and outcomes. They help decision makers understand the sensitivity of relevant systems, assess vulnerability, identify management alternatives, characterize uncertainties, and plan for implementation. For example, regional tools were developed during the development of the NACCI that allow web-based access to assessment data to assist in making agricultural crop decisions.

Adaptation to global change in general, and climate change in particular, requires that the institutional context of decisions be recognized in the development of decision-support tools and adaptation and mitigation activities. Assessments should be designed to be policy relevant without being policy prescriptive. There are many ways to ensure that decision-support efforts are properly focused and effective, but it will not be possible to support every type of decision at every scale. When selecting the specific case studies to be nested within the broader assessment activity, CCSP needs to be strategic about the kinds of decisions to support, and the scale at which such support is most urgently needed. It is also important that sufficient resources be dedicated to supporting the development of decision-support tools, which is a relatively new area of emphasis for CCSP. The critical issue in decision support is providing useful, policy-neutral information, targeted for use in particular sectors and for specific applications.

Recommendation: CCSP should foster and support the development of knowledge systems that effectively build connections between those who generate scientific information and the decision makers who are most likely to benefit from access to the knowledge that is generated. One approach is to support the development of decision-support tools and applications at various scales of decision making that can be used in the context of assess-

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ments. In doing so CCSP should identify decision-making processes of high priority or broad application that address key regional or sectoral vulnerabilities, and then evaluate the decision-support needs in those applications. New analytical and predictive tools can then be devised that have direct benefits in specific assessment applications.

NESTED MATRIX CONCEPT

Adaptive approaches are needed to continually integrate advances in knowledge into the policy context. Although it would be ideal to address impacts and responses for each sector at local, regional, and national scales, it is unlikely that sufficient resources will ever be available to do this comprehensively on an ongoing basis. One way to address this issue is to construct a broad conceptual framework or matrix linked to smaller-scale illustrative examples. For example, an assessment could be conducted at a national level, accompanied by selected localized case studies of impacts on specific sectors or implications for specific local decision making. The work on broad themes and trends can be an ongoing effort, while individual, integrated local, or sectoral assessments can be strategically nested in the broader research agenda. This will help develop an ongoing assessments program that has more coherence over time.

An example of the application of the nested matrix approach is using global climate models to identify likely future changes in temperature and precipitation at the national and regional level that may result from climate change. By connecting such outputs to hydrologic models, it is possible to identify a range of likely impacts on runoff for specific watersheds and evaluate potential vulnerabilities for regions and sectors. Based on that information, specific local or regional areas or sectors that are areas of high vulnerability can be selected for a more focused integrated assessment that includes the demographic and institutional context as well as physical parameters. At a regional scale, the vast amount of place-based information, including the additional drivers (e.g., land-use change), can be incorporated into the analysis to provide a more comprehensive treatment of potential changes in water quality and quantity.

Recommendation: CCSP should consider implementing this nested matrix concept in developing subsequent assessments.

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1

Introduction

The number of global environmental change assessments undertaken as a result of international treaties and at the request of national, state, and local governments is steadily on the rise. The amount of resources and the number of scientists dedicated to such assessment activities are increasing as well. At the same time, a wealth of experience on how to conduct assessments has become available. Given the expected increasing need for assessment activities in the future, it is important to evaluate the approach and effectiveness of past assessments and learn from the available lessons.

Many assessments in the past few decades have focused on concerns about natural and human-induced climate change, with the most recent U.S. assessment activity being conducted by the U.S. Climate Change Science Program (CCSP). The CCSP is responsible for implementing the Global Change Research Act (GCRA) of 1990, which mandates periodic assessments of our understanding of global change and its impact on the nation. Before undertaking its next round of assessments, the CCSP wanted to draw from the collective experience of the past few decades of global change assessments. Therefore, CCSP asked the National Academies to look at lessons learned from past global change assessments and to provide the program with guidance on its approach to the next assessment activity. In response, an ad hoc committee was formed by the National Academies to conduct a comparative analysis of past global change assessments (Table 1.1) with goals similar to those of the CCSP. The purpose is to identify strengths and weaknesses in these processes and provide advice for future assessments conducted in the United States. (See Box 1.1 for the Full Statement of Task).

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TABLE 1.1 The Eight Examples of Assessment Processes Included in the Comparative Analysis

Assessment	Brief Description
Stratospheric Ozone Assessments	Prior to the 1987 Montreal Protocol, several national (including NRC) and international assessments analyzed ozone-depleting chemicals and the current and projected state of the stratospheric ozone layer (WMO 1982, 1986a). Following the treaty, a system of expert advisory panels was established to periodically assess the atmospheric science of the ozone layer (WMO 1990a, 1990b, 1992, 1995, 1999, 2003, 2007), the impacts of ozone loss (UNEP 1991a, 1994a, 1998a, 2002a), and the technology and economics of alternatives to ozone-depleting chemicals (UNEP 1991b, 1994b, 1998b, 2002b).
Intergovernmental Panel on Climate Change (IPCC)	IPCC analyzes scientific and socioeconomic information on climate change and its impacts, and assesses options for mitigation and adaptation. On request, it provides scientific, technological, and socioeconomic findings to the Conference of the Parties to the United Nations Framework Convention on Climate Change (IPCC 1990a,b,c, 1995a,b,c, 2001a,b,c).
Global Biodiversity Assessment (GBA)	GBA provides a synthesis and analysis of available science to support the work of the UN Convention on Biological Diversity (GBA 1995).
National Assessment of Climate Change Impacts (NACCI)	NACCI was undertaken in response to the Global Change Research Act (1990) to evaluate the impacts of climate change on the United States (NAST 2001).
Arctic Climate Impact Assessment (ACIA)	Primary objectives were to evaluate and synthesize knowledge and indicators of climate variability, climate change, and ultraviolet radiation in the region; to assess possible impacts of future changes in climate and radiation; and to provide reliable information to both governments and peoples of the region to support policy-making processes (ACIA 2004).
Millennium Ecosystem Assessment (MA)	MA was designed to answer questions fundamental to various UN conventions dealing with natural resource issues, in particular the consequences of diverse environmental changes on the functioning of ecosystems, including their continuing capacity to deliver services essential to human well-being (MA 2005a,b).

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TABLE 1.1 Continued

Assessment	Brief Description
German Enquete Kommission on "Preventive Measures to Protect the Earth's Atmosphere"	The Enquete Kommission brings scientists and policy makers together to assess, in this case, the importance and consequences of stratospheric ozone depletion and climate change for Germany among other dimensions of global environmental change (Enquete Kommission 1988, 1991).
Synthesis and Assessment Products by the U.S. Climate Change Science Program (CCSP)	The 21 current assessment products were designed to address the mandate of the Global Change Research Act, by considering science and policy issues spanning the range of topics addressed by the CCSP. The first product, on temperature trends in the lower atmosphere, was released in April 2006 (CCSP 2006).

HISTORY OF CLIMATE CHANGE ASSESSMENTS AND POLICY IN THE UNITED STATES

Early History

In the United States, the first concerns about the ramifications of continued greenhouse gases can be traced to the late 1950s. In 1957, Roger Revelle, Scripps Institute of Oceanography, and Hans Suess, University of Chicago, suggested that the burning of fossil fuels would lead to significant increases in atmospheric carbon dioxide (CO_2) concentrations and that humans were engaged in a "large-scale geophysical experiment" with long-term consequences (Revelle and Suess 1957). Charles David Keeling, Scripps Institute of Oceanography, began taking regular measurement of CO_2 that same year at the Mauna Loa Observatory as part of the International Geophysical Year in 1957-1958. Keeling's early data showed a cyclical nature to annual Northern Hemisphere atmospheric composition that corresponds to the terrestrial "respiration" of the planet, as well as an overall upward trend superimposed on top of that cycle (Keeling et al. 1976, 1982).

In 1965, a report of the President's Science Advisory Committee (PSAC 1965) made clear that there was a sound basis for linking human activities to the increasing CO_2 concentration and that this would lead to global warming (Table 1.2). The panel recommended augmented research efforts and attention to this environmental issue. By the early 1970s, a number of international groups, including several that advised the United Nations, had come to the same conclusion. As recommended, U.S. research efforts were intensified during the 1970s. At the same time, several additional activities concluded that humans were indeed in the process of altering the Earth's

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BOX 1.1
Statement of Task

This committee was asked to identify lessons learned from past assessments to guide future global change assessment activities of the U.S. Climate Change Science Program (CCSP). The study had two steps.

(1) The committee conducted a comparative analysis of past assessments that have stated objectives similar to those of the CCSP. Specifically, the committee examined the strengths and weaknesses of selected past assessments in the following areas:

- Establishing clear rationales and appropriate institutional structures;
- Designing and scheduling assessment activities;
- Involving the scientific community and other relevant experts in the preparation and review of assessment products;
- Engaging the potential users of assessment products;
- Accurately and effectively communicating scientific knowledge, uncertainty, and confidence limits;
- Guiding plans for future global change research activities, including observation, monitoring, and modeling of past and future changes; and
- Creating assessment products that are valued by their target audiences.

(2) The committee identified approaches (in terms of geographic scale, scope, assessment entity, and timing) and products that are most effective for meeting the CCSP's stated objectives for assessments.

climate and made some climate projections into the twenty-first century that in many ways still hold true today (SMIC 1971, NRC 1977, 1979).

As a consequence of the many reports on the topic, Congress established the National Climate Program in 1978, as part of the National Oceanic and Atmospheric Administration, and charged the program to conduct climate impact assessments and study policy options for reducing human-induced climate change. This program was reviewed in a report of the National Research Council (NRC) and judged to be producing significant scientific achievements but falling somewhat short in terms of policy options. The NRC report *Toward an Understanding of Global Change: Initial Priorities for U.S. Contributions to the International Geosphere–Biosphere Program* (NRC 1988) called for expansion of the program to include disciplines that could study the socioeconomic impacts of various policy options.

The 1985 Villach report (WMO 1986b) by an international climate change conference renewed the interest of policy makers internationally

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TABLE 1.2 Selected Activities during the 1970s and Early 1980s Highlighting the Concern that Humans Are Influencing Global Climate and Environment by Increasing CO_2 Emissions

Year	Activities
1965	U.S. President's Science Advisory Committee (PSAC) points to sound basis for link between human activities and increasing CO_2 emissions (PSAC 1965).
1970	Study of Critical Environmental Problems (SCEP) highlights man's impact on the global environment (SCEP 1970).
1971	Study of Man's Impact on Climate (SMIC) points out the inadvertent climate modification due to human activity (SMIC 1971).
1977	National Resource Council (NRC) report *Energy and Climate* points to potential negative impact of heavy coal use on climate (NRC 1977).
1979	NRC report *Carbon Dioxide and Climate: A Scientific Assessment* concludes that climate sensitivity to a doubling of CO_2 is 1.5 to 4.5°C (NRC 1979).
1979	American Association for the Advancement of Science workshop in Annapolis on climate impacts, sponsored by DOE, led to congressional hearings in 1981 with a call for the Administration to fund research on impacts.
1983	NRC report *Carbon Dioxide and Climate: A Second Assessment* confirms the first report's finding regarding climate sensitivity and predicts the doubling to occur during the last quarter of the century. It calls for research into energy sources other than fossil fuel and suggests that if addressed now, climate change from greenhouse gases would be manageable (NRC 1983).
1985	During an international meteorologist conference jointly sponsored by the United Nations Environment Programme (UNEP), World Meteorological Organization (WMO), and International Council of Scientific Unions in Villach, Austria, a consensus is announced that, in the first half of the twenty-first century, a rise in global mean temperature could occur that is greater than any in man's history (WMO 1986b).

and nationally and was followed by several congressional hearings on this issue. The Reagan White House responded to these hearings by forming a White House Domestic Policy Council working group on climate change. Although the House of Representatives held hearings throughout the 1980s on the topic of rising CO_2, the Senate did not turn to this issue until after the Villach report (WMO 1986b). After numerous hearings, Congress enacted the Global Climate Protection Act of 1987 (P.L. 100-204), which authorized the U.S. Environmental Protection Agency and the State Department to

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develop climate change policy. However, both the Reagan and the G.H.W. Bush administrations limited the impact of the Global Climate Protection Act by retaining control over climate change policies in the executive office (GAO 1990). The efforts of various White House committees to coordinate climate science and provide the executive branch with policy options did not satisfy the desire of Congress to see progress on these issues.

U.S. Global Change Research Program and Global Change Research Act Of 1990

In 1989, the U.S. Global Change Research Program (GCRP) was developed by the Committee on Earth Sciences, an interagency group under the Federal Coordinating Council for Science, Engineering, and Technology in the President's Office of Science and Technology Policy. The GCRP was a Presidential Initiative indicating that it was a high-priority program with strong administrative backing. In 1990, Congress passed the Global Change Research Act (GCRA) (P.L. 101-606), which codified the GCRP (see Appendix B). According to this law, the GCRP is aimed "at understanding and responding to global change, including the cumulative effects of human activities and natural processes on the environment, to promote discussions toward international protocols in global change research, and for other purposes."

The GCRP was originally envisioned as a complete global change research program, covering research on natural climate change, human-induced climate change, impacts of climate and land-use change on the Earth system, and impacts of human activity on ecosystem health. Much of the research effort that was assembled into the GCRP originated with the National Aeronautics and Space Administration's "Mission to Planet Earth" that formulated an interdisciplinary program to study the Earth as a total system in the early 1980s (CRS 1990). The GCRP's priorities were established with input from the scientific community under the guidance of the Committee on Earth Science (see Figure 1.1) and published in "Our Changing Planet: A U.S. Strategy for Global Change Research" (GCRP 1989). Several criteria, although not applied systematically, were used to evaluate projects under each research element, including relevance and contribution to the overall goal of the program, scientific merit, ease or readiness of implementation, links to other agencies and international partners, cost, and agency approval.

Initially, the early GCRP mission included the following:

- Documentation and analysis of Earth system changes, which include observation—using both ground- and space-based observation systems—and data management; and

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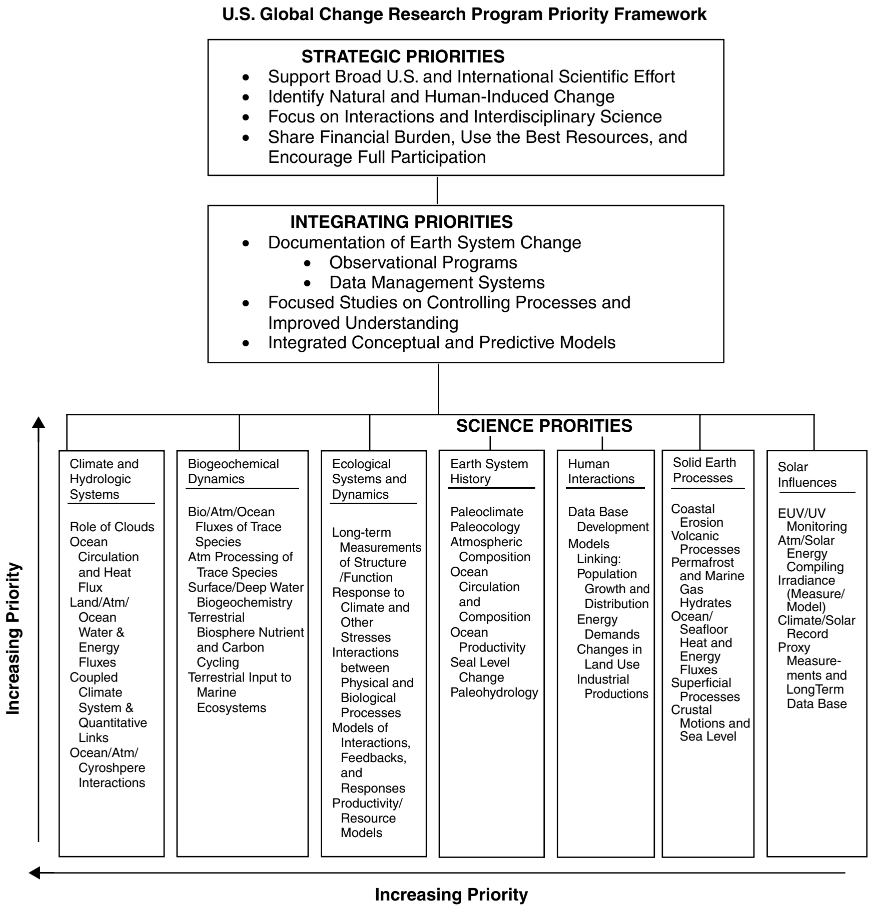

FIGURE 1.1 The goal, objectives, and scientific framework for the U.S. Global Change Research Program (GCRP) with a ranking of science priorities. SOURCE: GCRP 1989.

- Process research to enhance understanding of the physical, geological, chemical, biological, and social processes that influence Earth system behavior; and integrated modeling and prediction of Earth system processes.

In FY 1994, a new program element was added: assessment activities. This addition came in response to Congressional interest as specified in the GCRA and advanced many of the findings of the Congressional Office of Technology Assessment (OTA) report (OTA 1993) *Preparing for an Uncer-*

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tain Climate that recommended more effort be put into assessment, analysis of climate impacts, contingency planning, and adaptation.

Specifically, the GCRA calls for preparing and submitting to the President and Congress an assessment that:

- Integrates, evaluates, and interprets the findings of the GCRA;
- Analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and
- Analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

Between 1994 and 1997, the GCRP conducted detailed annual reviews of both its core programs and areas in need of additional research, such as assessment and impacts. Each annual *Our Changing Planet* report highlighted the programmatic foci of the next year and the successes of the previous years. In 1997, the administration charged the GCRP to initiate the first comprehensive National Assessment. This effort, the National Assessment of Climate Change Impacts, was completed in the fall of 2000, after 20 regional workshops, 5 sectoral analyses, 2000 participants, and 3 layers of review (for additional details, see Chapter 4).

Over the years, the GCRP benefited from ongoing external oversight provided by several boards, committees, and panels of the NRC. The NRC was responsible for evaluating the GCRP periodically for scientific merit and issued more than 30 reports that advised the GCRP on global change research (e.g., NRC 1988, 1989).

The Genesis of the Climate Change Science Program

On June 11, 2001, President G.W. Bush announced that his administration would "establish the U.S. Climate Change Research Initiative to study areas of uncertainty [about global climate change science] and identify priority areas where investments can make a difference." The Secretary of Commerce, working with other agencies, was directed to "set priorities for additional investments in climate change research, review such investments, and to improve coordination amongst Federal agencies."

To respond to the President's initiative and meet the requirements of the GCRA of 1990, the CCSP was initiated in 2002. Thirteen federal departments and agencies that fund or carry out global change research participate in the program and serve on the CCSP Interagency Committee, which is chaired by the CCSP Director, who is the Assistant Secretary for Oceans and Atmosphere. An Interagency Working Group appointed by the Interagency

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Committee and consisting of specialists from the participating departments and agencies is responsible for implementing CCSP activities.

A 10-year strategic plan to coordinate climate and global change research activities across federal agencies was developed (CCSP 2003) with input and review from an NRC committee (NRC 2003, 2004). The strategic plan identified five overarching goals (see Box 1.2), a wide range of research areas, and 21 synthesis and assessment activities to address these goals (Appendix C). The Climate Change Research Initiative (CCRI) represents a more focused program than the GCRP, dedicating its resources and attention to those elements of the GCRP that can best support improved public debate and decision making in the near term. In particular, a goal of the CCRI is to improve the integration of scientific knowledge, including measures of uncertainty, into effective decision-support systems. The CCRI intends to deliver products useful to policy makers in a short time frame (two to five years). To meet this goal, the CCRI aims to (1) reduce the most important uncertainties in climate science and advance climate modeling capabilities,

BOX 1.2
Vision and Goals of the CCSP

CCSP's vision for the program:

> A nation and the global community empowered with the science-based knowledge to manage the risks and opportunities of change in the climate and related environmental systems.

CCSP's goals for the program:

- Improve knowledge of the Earth's past and present climate and environment, including its natural variability, and improve understanding of the causes of observed variability and change.
- Improve quantification of the forces bringing about changes in the Earth's climate and related systems.
- Reduce uncertainty in projections of how the Earth's climate and related systems may change in the future.
- Understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes.
- Explore the uses and identify the limits of evolving knowledge to manage risks and opportunities related to climate variability and change.

SOURCE: CCSP 2003.

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(2) enhance observation and monitoring systems to support scientific and trend analyses, and (3) improve decision-support resources.

DEFINITIONS OF KEY TERMS

Definition of Assessment

The committee has adopted the following definition of assessments, which is derived from its usage in the emerging literature (Parson 2003; Farrell et al. 2006):

> Assessments are collective, deliberative processes by which experts review, analyze, and synthesize scientific knowledge in response to users' information needs relevant to key questions, uncertainties, or decisions.

Embedded in this definition are three important and often underappreciated characteristics of assessments that need to be emphasized (Mitchell et al. 2006). First, assessments are processes that connect the domains of science and decision making (either public policy or decisions by some other actor) but differ significantly from both. For example, process assessments seek to build consensus around the latest scientific information, which is clearly distinct from the scientific process that solely reports observations and experimental results. Therefore, assessments cannot be evaluated according to the same criteria as either the process of democratic policy making or science (Clark and Majone 1985). Second, as mentioned in the definition, an assessment is a social, deliberative process and not merely an exercise of transcription or deduction. Rather, it involves synthesis directed toward a goal of supporting decisions, and its character is in many ways driven by the interaction of the state of scientific knowledge with the societal need for decision-relevant information. Third, while an assessment may generate a report, this is neither necessary nor the totality of the process. Some assessments do not yield reports, and for all assessments the process may be as effective as the report in affecting the decision-making process if the stakeholders and target audience are involved in the assessment process (Farrell et al. 2006).

Defining Success: The Effectiveness of Assessments

Assessments seek to inform decisions. It follows, therefore, that a measure of the effectiveness of an assessment would be its incorporation in the decision-making process. In some cases, it is possible to make a qualitative judgment about the impact an assessment has had on decision making; however, in practice, it is difficult to evaluate what other information has been considered by decision makers and how the value of the information

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was weighted in the process (Social Learning Group 2001a). Economic analyses, along with numerous social and political factors, also influence decision makers, and it is virtually impossible to separate the impact of these factors from that of the assessment itself. Furthermore, a reliable evaluation of the ultimate impact of an assessment can only be done in retrospect, which requires a historical perspective not yet available for many of the assessments the committee analyzes in the following chapters (Social Learning Group 2001a).

In view of the difficulty of evaluating an assessment's effectiveness by its ultimate effect on decisions, assessment scholars have identified proximate (i.e., less dependent on context) characteristics that can be attributed to the assessment itself and that are plausibly linked to increased likelihood of ultimate effectiveness. A prominent set of such indicators has been developed by the Social Learning Group (2001a) and applied successfully in the Global Environmental Assessment project (Farrell et al. 2006; Mitchell et al. 2006). The literature identifies three essential properties of effective assessments: credibility, legitimacy, and salience (Ravetz 1971; Clark and Majone 1985; Social Learning Group 2001a; see also Box 1.3).

Credibility concerns the technical quality of an assessment, as perceived by relevant scientific or other expert communities. Achieving credibility requires that the assessment avoids clear errors; involves respected experts with the right competencies; shows understanding of the relevant scientific

BOX 1.3
Salience, Credibility, and Legitimacy

The three essential properties of an effective assessment process are:

- *Salience* relates to the perceived relevance of information: Does the system provide information that decision makers think they need, in a form and at a time that they can use it?

- *Credibility* addresses the perceived technical quality of information. Does the system provide information that is perceived to be valid, accurate, or tested?

- *Legitimacy* concerns the perception that the system has the interests of the user in mind or, at a minimum, is not simply a vehicle for pushing the agenda and interests of other actors. Legitimacy relates to the perceived fairness of the process.

SOURCE: Ravetz 1971; Clark and Majone 1985; Social Learning Group 2001a.

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literature; makes use of accepted datasets, methods, tools, and models; and undergoes a scientific peer-review process.

Legitimacy concerns the fairness and impartiality of an assessment, as perceived by all its users and stakeholders. It reflects their judgments that the assessment gave regard to their interests and concerns, at least was not simply a vehicle to advance the interests and concerns of some other actors. Concerns about legitimacy are most frequently expressed as objections to an assessment's process. Achieving legitimacy depends on matters such as involving participants who represent a variety of key stakeholder groups, running a transparent process, providing avenues for input and consultation, and submitting the assessment to an open review process.

Salience concerns an assessment's ability to communicate with the users whose decisions it seeks to inform. Achieving salience depends on such matters as capturing users' attention, addressing matters that are relevant to their concerns, communicating in terms they can understand, and presenting any recommendations in operational terms to the audience that can use them, at the time it needs them.

Although these are rather academic concepts, they have attained widespread use both among scholars and in practical debates about assessment programs. The committee has found these criteria useful in analyzing assessment effectiveness. However, the committee recognized three points for which further clarification is required.

First, these characteristics are ascribed by stakeholders and are not inherent characteristics of assessments. Therefore, they result from subjective judgments of the process, and the goal is to increase the number of stakeholders that attribute these characteristics to the assessment process. Certain stakeholder groups may diverge in their judgment of the process regardless of how well it was designed and implemented.

Second, during the committee's deliberation it became evident that there is the potential for confusion about the difference between credibility and legitimacy. This confusion is understandable because both credibility and legitimacy are fundamentally concerned with whether people judge that an assessment can be trusted. They must be distinguished, however, because they concern trust granted to an assessment by different audiences for different reasons. Credibility is ascribed by scientific experts if they regard an assessment as trustworthy, based on indicators similar to those they use to evaluate the trustworthiness of other scientific work (Social Learning Group 2001a). Stakeholders ascribe legitimacy if they regard an assessment as trustworthy, based on indicators of fairness, balance in representation, and transparency of the process similar to those they use to evaluate the trustworthiness of political, administrative, or legal processes. Drawing a clear distinction between credibility and legitimacy highlights the fact that

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both types of trust may be required, but how each is earned might require different design choices and trade-offs between the two.

Third, the term salience combines several characteristics that are all associated with effective communication with the intended audience (Ravetz 1971; Clark and Majone 1985; Social Learning Group 2001a). Most important, it includes the need for an assessment to be simultaneously relevant and widely recognized in order to capture users' attention and, therefore, communicating in terms that they recognize as relevant to their concerns. Depending on the particular assessment and context, it may also include communicating through the right media, expressing results at a technical level, using terms and concepts that are matched to the audience, and taking regard of specific decision responsibilities and deadlines.

Other Key Terms

Stakeholders. The committee considers all "interested and affected parties" as stakeholders in the assessment process. This includes people whose material interests may be affected and also those who have an interest as citizens even if they do not stand to be materially affected. A distinction is made in this report between these and a specific stakeholder—the authorizing body of the assessment—that provides the assessment with its mandate and typically also with its funding. Most often, the authorizing body (i.e., those requesting an assessment) is part of a government or, in the case of the IPCC, of multiple governments. This distinction is made for the purpose of several discussions in this report, due to the fact that different processes may be required to structure the participation of the authorizing body and of all other stakeholders.

Target audience. This refers to the potential users of assessments. Often, the primary target audience consists of decision makers in the federal government who are responsible for the decisions that the assessment is intended to inform. In addition, the target audience may also include state and municipal governments, private-sector users, the public, or intermediaries, who function as science translators to decision makers (e.g., congressional staff, business associations, environmental organizations).

Framing. Framing refers to the process of defining the mandate of the assessment and the specific questions it is charged to address. In the framing process, the types of decision the assessment is intended to inform are identified together with the approach.

STUDY APPROACH AND REPORT ROAD MAP

The requested analysis of past global change assessments involved a three-pronged approach: building on existing scholarly work, drawing from

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committee members' collective experience as scholars and practitioners of assessments, and conducting some empirical analyses of selected case studies. The composition of the committee was such that it could draw from a broad range of experiences in various assessments. Besides representing many different scientific disciplines, committee members were selected to represent several major stakeholder groups: academia, decision makers, the private sector, and nongovernmental organizations. As instructed by the Statement of Task, the committee focused its analysis on assessments with goals similar to the CCSP's. Despite the fact that this represents a relatively limited sample of assessments, the committee recognized the diversity of external and internal factors that can lead to success and the need to distinguish assessments based on their external conditions and goals when comparing and drawing conclusion regarding assessment design. Chapter 2 elaborates further on this distinction and provides a framework to illustrate the relevant factors in the assessments process, such as the context at the inception of the assessment, the conditions established at that time, and the design choices made within the conduct of an assessment. Chapter 3 reviews the scholarly literature on assessment processes to identify the key challenges in designing an effective assessment. It also draws some conclusions from the literature on what design choices increase the likelihood for an effective assessment. Based on the general framework provided in Chapter 2 and the key challenges identified in Chapter 3, the committee analyzes a selection of assessments in Chapter 4 and identifies the strengths and weaknesses in their approaches. Drawing from the literature review in Chapter 3, the analysis in Chapter 4, and Chapter 5 concludes with the committee's overall findings and recommendations.

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Diversity of Assessments and Their Potential Contributions

When looking at lessons learned from diverse global change assessments, it is important to consider the science and decision-making context in which each assessment was undertaken and the kind of decisions the assessment was intended to inform. Because the effectiveness of any assessment approach depends on the context and goals of the assessment, the committee describes the role of both in distinguishing various assessment types. The committee groups assessments into four general types: (1) process assessments, (2) impact assessments, (3) response assessments, and (4) integrated assessments. This classification is consistent with and frequently encountered in the assessment literature (Smit et al. 1999; Parson 2003; Farrell et al. 2006; Fussel and Klein 2006; Martello and Iles 2006).

POTENTIAL CONTRIBUTIONS OF ASSESSMENTS TO DECISION MAKING

Any attempt to ascribe a single, general definition of success or effectiveness to assessments has encountered fundamental problems. These problems stem from the diversity of contexts in which assessments are conducted; the diversity of assessment strategies, which results from the variety of goals and potential contributions; and the fact that assessments are evaluated by multiple actors with distinct perspectives and interests. Consequently, when evaluating the effectiveness of a particular assessment the following

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questions must be considered: Effective according to whom? Effective in achieving which goals over what time frame?

Despite this diversity, the record of past assessments indicates certain specific categories of contributions that assessments can make to policy debates or to decision making. Illustrative examples of such contributions are given below (Mitchell et al. 2006). While this list is not exhaustive, it captures the most important categories of contributions that are evident in the record of global change assessments of the past 30 years. Note that the ability of an assessment to make any of these types of contributions depends on the state of both the scientific and the policy context in which the assessment is conducted.

1. ***Assessments have the potential to establish the basic significance or importance of an issue and elevate it onto the decision-making agenda.*** If an issue is not yet on the agenda of decision makers, which have with the authority and resources to address it, an assessment that assembles an review of evidence can make the case that it is serious or urgent enough to deserve their attention. The stratospheric ozone trends panel (WMO 1990a) and the Villach report (WMO 1986b), for example, exerted a decisive influence over the policy debate by showing the seriousness of ozone depletion and climate change, respectively. In fact, when the policy context for an issue is immature, this may be the only contribution that an assessment can make.

2. ***Assessments have the potential to provide authoritative resolutions of policy-relevant scientific questions.*** Sometimes particular scientific questions come to be widely perceived as important, perhaps even decisive, for policy decisions. Important examples include the significance of an environmental change (e.g., how much ozone depletion is required to significantly impact the skin cancer rate?), the significance of the human contribution to a naturally occurring change, or discrepancies in data records or observational techniques. If the policy debate on an issue is characterized by controversy or deadlock because conflicting claims are being made about key scientific questions, an assessment can inform and advance the policy debate by authoritatively resolving these questions. Such a contribution requires both that available scientific knowledge is able to support a clear resolution and that there is a policy-making body with the issue on its agenda.

3. ***Assessments have the potential to link actions to consequences.*** When the policy context is even more advanced—in that a decision forum and agenda have been established, a specific set of options is being considered, and actors broadly agree on the consequences of these choices—assessments can inform decisions by making specific, scientifically founded

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statements that link alternative trends in human drivers or alternative actions to limit these drivers to specific environmental changes. The Intergovernmental Panel on Climate Change (IPCC) Working Group III on mitigation of climate change (IPCC 2001c) is a good example. Assessments can also provide scientific evaluations of adaptation strategies, such as in the case of the IPCC Working Group II on impacts, adaptation, and vulnerability (IPCC 2001b). As with all these types of contributions, the ability of assessments to effectively link actions and consequences depends both on an adequate base of scientific knowledge and on policy actors willing to support the activity and consider acting on its results.

4. ***Assessments have the potential to help solve recognized, shared technical problems.*** If most or all members of a relevant decision-making body perceive themselves to have a specific, shared problem, an assessment can make a significant contribution by bringing the principal parties together to find common technology options and solutions that solve their problem. An example is the Technology and Economic Assessment Panel (TEAP) that provides technical advice to the Montreal Protocol regarding alternatives to ozone-depleting substances.

5. ***Assessments have the potential to help identify and clarify key policy-relevant questions or research priorities.*** If the policy-relevant questions are vague or confused, instruments and models give conflicting results, or there are other serious conflicts in the field, assessments can provide disciplined settings to force confrontations between contending claims, sharpen disagreements, clarify incompatible terminology or concepts, and develop a research agenda to advance knowledge on key policy-relevant questions. Examples of assessments that have made contributions of this sort include IPCC's Working Group I report (IPCC 2001a) and the Arctic Climate Impacts Assessment (ACIA 2004).

6. ***Assessments have the potential to demonstrate that a policy is providing environmental benefits.*** For example, the process assessment of stratospheric ozone assessment conducted under the Montreal Protocol provided evidence that the new policies were effective in reducing negative impacts on the ozone layer.

SCIENTIFIC AND POLICY CONTEXTS FOR ASSESSMENTS

The context for any global change assessment has two primary components: (1) the scientific context, which concerns the state of relevant knowledge to be assessed; and (2) the policy and political context, which concerns the state of relevant policy debates and decisions that the assessment seeks

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to inform. When analyzing or evaluating an assessment, it is crucial to consider these two components of the context in which it is conducted. These exercise fundamental influence over when and even whether an assessment can be undertaken, what contributions it can make, which approach holds most promise, and by what criteria it can be evaluated. The effectiveness of any given assessment approach depends on how well the scope of the assessment fits within the scientific and political context; hence, both need to be considered prior to framing the assessment.

The Scientific Context

An important aspect of the scientific context is the maturity, understanding, and degree of consensus in the relevant fields and on the most central questions of concern (Ravetz 1971). In particular, the wealth of evidence and data available to address the science issues plays a crucial role in the type of assessment that can be undertaken. It is important to consider the maturity of the field and whether the relevant knowledge lies within one or several research disciplines. If it spans multiple disciplines, a certain capacity building is required for the experts from various fields to be able to communicate and find agreement on approaches to the questions of concern.

The Policy and Political Context

Together with the science context, the policy and political context determines what an assessment can contribute and, in many ways, what its mandate, goals, and approach ought to be. At an early stage of maturity in the policy context,[1] an issue might not have risen to the importance of being included on the policy agenda because the potential decisions to be considered are not clearly identified (Social Learning Group 2001b). At this early stage in the public attention cycle, the goal of an assessment ought to be to establish the importance of an issue, which might increase the public's attention and bring the issue onto the decision-making agenda. For example, the Villach report (WMO 1986b) was an assessment that brought the issue of climate change onto the policy agenda.

Once relevant decisions have been identified and have entered the policy agenda, the focus on a global change issue depends on whose agenda it is and how much attention the issue is being given. Often the attention is

[1]Rather than established orders, policies are changing phenomena. Scholars identify stages in the context of policy making. During the first stage, an issue rises to such public importance or maturity within the policy context that a group of people decide it must be addressed in a *political process*. The stages that follow are goal and strategy formulation, implementation, and evaluation of actions and measures (see Social Learning Group 2001b).

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short-lived as other more pressing issues replace it. In addition, when the issue is being considered in the decision-making process, the ability to make progress becomes a question of (1) the level of disagreement over actions or decisions to be taken and (2) if there is disagreement, the source of such. In particular, to what extent are actors basing their policy arguments on scientific claims? At this point, assessments will be required that not only advance the consensus in the basic understanding of the process and its impact but also analyze potential policy options and response options.

FOUR TYPES OF ASSESSMENTS AND CONSEQUENCES FOR DESIGN CHOICES

The type of assessment to be undertaken depends largely on the science and policy context, which in turn limits many internal design choices at the inception of the assessment. Therefore, it is important to keep in mind that some key dimensions of an assessment are established by conditions external to the assessment at its inception.

Conditions Established at the Assessment's Inception

The Institutional Setting and Authorizing Environment

This first dimension concerns issues such as: Who asked for the assessment or gave permission to do it? What organizations have provided official sponsorship and on what terms? Who is funding it? To whom is its output addressed? Although these issues may appear similar to the types of factors that define the assessment's policy context, it is important to distinguish them. Whereas the policy context of an assessment concerns historical conditions around the relevant issues at the time the assessment is established and conducted, which one cannot choose, the issues presented here are established at the inception of a particular assessment. For example, there are many variants in the institutional setting of assessments, some of which can be identified according to their degree of official connection to international policy-making bodies:

- Assessments conducted under the auspices of an official policy-making body (e.g., World Meteorological Organization stratospheric ozone assessments);
- Assessments sponsored by international or intergovernmental bodies that do not have direct decision-making authority and those sponsored by multiple national bodies (e.g., IPCC assessments);

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- Assessments sponsored and authorized by national governmental bodies (e.g., National Assessment of Climate Change Impacts [NACCI]); and
- Independent, ad hoc assessments, with various weaker degrees of linkage to official or decision-making bodies (e.g., Global Biodiversity Assessment).

The Scope and Mandate

Global change assessments can be classified into four categories based on their mandate and goals: (1) process assessments, (2) impact assessments, (3) response assessments, and (4) integrated assessments. This four-part distinction matches the most common usage in the literature, although other terms have been proposed (Smit et al. 1999; Parson 2003; Farrell et al. 2006; Fussel and Klein 2006; Martello and Iles 2006). Just as these categories of assessments differ in the types of questions they answer, they also differ in the complexity of the analysis necessary to answer those questions. As a result, they may diverge in the approach necessary to enhance salience, credibility, and legitimacy.

The committee recognizes that none of the terms used to categorize assessments are wholly satisfactory, that this division does not represent a model that should be applied to all assessments, and that most assessments are hybrids of these ideal types to some degree. The taxonomy simply matches the historical practice of global change assessments. For example, the first three types of assessments roughly mirror the mandates of the IPCC Working Groups (WGs) I, II, and III, and of the Montreal Protocol's Scientific Assessment Panel, Environmental Effects Assessments Panel, and TEAP. Although this division has sometimes been criticized by academics as being too simplistic and various attempts have been made to reorganize IPCC working groups along different boundaries, there are quite robust differences among the three in how they must be (and have been) organized and what conditions determine their effectiveness. Figure 2.1 illustrates the "space" an assessment can occupy, depending on how much attention it gives to each of the three questions. Integrated assessments attempt to incorporate all three.

Process Assessments: Understanding What Global Changes Are Occurring and What Is Causing Them

The goal of process assessments is to summarize and synthesize scientific knowledge of global change processes, rather than their impacts or responses to global change. Often such process assessments are initiated first due to the need to characterize the extent and the drivers of change.

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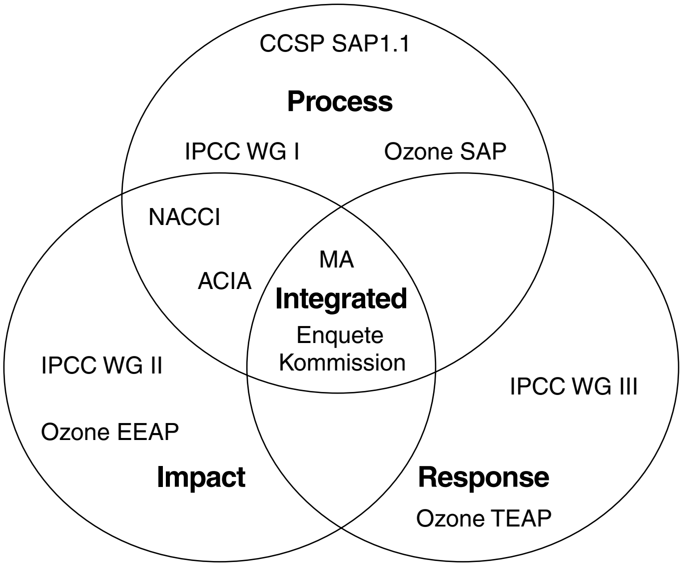

FIGURE 2.1 Three types of global change assessment: process assessment, impact assessment, and response assessment. The fully integrated assessment lies at the intersection of the three types. Examples of assessments are included. ACIA = Arctic Climate Impact Assessment; CCSP SAP 1.1 = U.S. Climate Change Science Program Synthesis and Assessment Product 1.1 on Temperature Trends in the Lower Atmosphere; IPCC WG I, II, and III = Intergovernmental Panel on Climate Change Working Groups I, II, and III; MA = Millennium Ecosystem Assessment; NACCI = U.S. National Assessment of Climate Change Impacts; Ozone EEAP = Environmental Effects Assessment Panel of the stratospheric ozone assessments; Ozone SAP = Scientific Assessment Panel of the stratospheric ozone assessments; Ozone TEAP = Technology and Economical Affects Panel of the stratospheric ozone assessments.

An understanding of environmental processes and their drivers is required to examine impacts and especially responses.

The most prominent examples of process assessments are the Montreal Protocol Scientific Assessment Panels (WMO 1990a,b, 1992, 1995, 1999, 2003, 2007) and the IPCC WG I (IPCC 1990a, 1995a, 2001a).

To date, process assessments have generally focused on Earth system and ecological processes. Most participants come from the physical, chemical, and biological sciences. Of course, in the history of global change issues one of the key questions is not only whether global change is occurring but also whether it is driven by human action. Thus, while often centered in the natural sciences, these assessments also consider, explicitly or implicitly, human activity. They may describe the status of current and past trends in these processes

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(e.g., climate trends and patterns of variability), explain the causal mechanisms that determine their dynamics, and, in some cases, include projections of future trends. To date projections have relied on simple, exogenously specified assumptions about future human perturbations (e.g., specified scenarios of trends in anthropogenic emissions are used for projecting future trends in stratospheric ozone and climate change). Process assessments have typically drawn on knowledge and participation either from one well-defined research community, from a few closely related ones, or, in case of the most interdisciplinary problems, from most disciplines in the natural sciences.

Process assessments have the potential to make the following types of contributions to policy debates and decision making. They can influence science-policy decisions by clarifying and prioritizing key research questions. In addition, they can demonstrate the accumulation of baseline knowledge and data on an issue, making the initial case for the credibility of the relevant scientific knowledge and the seriousness of the related environmental threat. This contribution typically takes place early in the development of an environmental issue and, once achieved, can make a qualitative change in the subsequent policy debate.

Impact Assessments: Understanding the Consequences of Global Change

Impact assessments seek to characterize, diagnose, and project the risks or impacts of the environmental change on people, communities, economic activities, ecosystems, and valued natural resources. As the history of climate change assessments and of stratospheric ozone assessments indicates, impact assessments often occur once a global change phenomenon has been validated by a process assessment and they often draw on the outputs of the process assessment. The most prominent examples are the IPCC WG II and Millennium Ecosystem Assessment (MA) reports.

Because most impacts play out within specific sectors (e.g., water resources, forestry, agriculture, fisheries) and at regional scales, impact assessments often focus on individual economic sectors or regions. For example, NACCI examined five sectors and nine megaregions in the United States and concluded that the impacts of climate change vary substantially across sectors and regions. Further, the impact on a sector will often differ across regions. In contrast to this context dependence, a process assessment can often do useful work at the global scale. This factor alone makes impact assessments quite complex. Impact assessments must also consider interactions among impacts, so that every impact assessment is to some extent an integrated assessment. Because of their complexity, impact assessments always require scientific input from many disciplines. In addition, the sectoral and regional specificity of impacts requires input from diverse stakeholders who provide critical local and sectoral information.

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For these reasons, impact assessments are large and complex endeavors and require resources and organizational structures commensurate with their scale. Yet, their contribution to decision making is fundamental. While a process assessment can identify and characterize an anthropogenic global change, without sound analysis of impacts, decision makers cannot make an informed decision about the importance of responding. Impact assessments answer the "so what?" question, identify key vulnerabilities, and potential strategies to enhance resilience.

Response Assessments: Understanding the Options for Responding to Global Change

Response assessments seek to identify and evaluate potential responses that could reduce human contributions or vulnerabilities to the environmental perturbation at issue. They have also been referred to as option assessments (Social Learning Group 2001b). Some response assessments are focused narrowly on technology responses, mitigation, or adaptation and are referred to as such. Other response assessments are broader and may consider a variety of options, including changes in technology, policy, economic incentives, and mitigation or adaptation. The scale at which "what can be done" is considered may be economy-wide or specific to particular industry sectors, production processes, or individual firms. It may also be regional, national, or global. The measures considered certainly include alternative technologies but may also include process, product, managerial, organizational, or institutional changes brought about by either public or private policy. The questions posed may include identifying options (currently available or anticipated); assessing their feasibility, their state of development, and their potential contribution to solving the problem; and assessing their costs and benefits broadly, including monetary costs, their effects on factors such as yield, reliability, and product quality; and their contributions to other environment, health, and safety issues.

Again, it is important to remember that the four types of assessments are not perfectly distinct, and many fall on the spectrum between impact and response assessments. In particular, it is usually important to understand the full impacts of a response strategy. The exception may be when the response strategy is confined to technological choices within a sector that have few impacts outside that sector. In fact, because response assessments focus on reducing human drivers of the environmental change or on ways to mitigate their impact, there is a logical coupling between these and process assessments, mediated by scenarios (of emissions or of other anthropogenic perturbations) or models that can be used to drive projections of future environmental change in the process assessments. Process and response assessments together have a logical structure that considers natural and

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human factors, and potential interventions in terms of the human factors. Therefore, the development of scenarios linking the two assessment types needs rigorous social science engagement to ensure that human factors are represented realistically (Social Learning Group 2001b).

Integrated Assessments: Understanding the Connections

Integrated assessments examine the links among the systems analyzed in process, impact, and response assessments. It is useful to differentiate two types of integrated assessments. Fully integrated assessments develop a common model of the world, generally a computer model. Sometimes this is done by linking models developed for narrower purposes, as in the efforts to link climate models to economic models. Linked assessments are a mix of process, impact, and response assessments in which the assessment teams actively communicate, coordinate, and build as much as possible on each others' work. Many assessments attempt to integrate the three components through a synthesis report that pulls together (or sometimes merely juxtaposes) results and conclusions. The working groups of the IPCC follow this model. Other assessments are designed from the outset to analyze the individual pieces but with a deliberate strategy and common framework so that the various pieces can be integrated by a team into a synthesis report. This approach was used by the MA and NACCI.

Under common definitions (e.g., Weyant et al. 1996; Parson and Fisher-Vanden 1997), synthesis reports as undertaken by the IPCC or the MA would not qualify as integrated assessments. However, because of the importance of providing integrated information for decision making and the complexities of conducting integrated assessments, the committee believes that consideration of the less stringent forms of integration is also important to the design of assessments.

As noted, timing is a critical issue for linking assessments. A logical sequence would suggest that a process assessment should be completed before impact and response assessments so that the latter can benefit from the most updated understanding of the processes. In turn, the impact and especially the response assessments can inform assumptions about human activities that should be deployed in subsequent process assessments. However, mandates of many assessments do not allow this phased approach, instead requiring parallel activities. Sequencing activities so that process, impacts, and response assessments are conducted on an iterative cycle may be more effective.

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Design Choices Made During the Conduct of an Assessment

Those leading and participating in an assessment must operate within constraints imposed by prior decisions defining an assessment's scope, mandate, and organizational setting. Even so, assessment participants still have the opportunity to decide many aspects of its process, content, and presentation. Within an assessment's previously defined mandate, participants choose what specific subject areas to include or emphasize, what sources of information to include, what methods or tools to use in integrating information, and what (if any) specific policy-relevant questions to answer. They may decide who participates in the assessment, how they are chosen, how they organize their collective work, how they make decisions (particularly in the case of disagreements), and how to identify and involve stakeholders. They choose how to present results, including the content and strength of conclusions, as well as whether to make interpretive judgments that go beyond the present literature, to employ "if-then" statements that link alternative choices to potential outcomes, or to include explicit recommendations for action. They may decide whether the assessment undergoes public or governmental review in addition to scientific peer review. They also decide the scale, form, and manner of dissemination of reports or other outputs.

Many of these design choices are linked with an assessment's success in achieving credibility, legitimacy, and saliency, although the relationships are both complex and dependent on the assessment's context. For example, broadening stakeholder participation in an assessment can increase legitimacy but poses risks to credibility to the extent that these participants are perceived as lacking expert standing, thereby, diminishing the assessment's reliance on scientific expertise. In Chapter 3, the committee discusses in greater detail how these mostly internal design choices can be approached to optimally balance all three attributes in achieving an effective assessment.

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Major Challenges to Achieving an Effective Assessment Process

Despite the diversity of assessment contexts and types of assessments, some common challenges can be identified. If these challenges are addressed adequately, there is a greater likelihood that the assessment process will effectively inform the target audience and the decision-making process. There is an extensive body of literature in which these challenges have been identified. This chapter provides a summary of the evaluation of assessments available in the literature.

FRAMING A CREDIBLE AND LEGITIMATE PROCESS

Framing the assessment process such that it is perceived as credible and legitimate by all relevant stakeholders is a major challenge (Farrell et al. 2001). The leading social science theories of trust in the policy process (e.g., Ostrom 1998; Leach and Sabatier 2005) indicate that trust comes from two sources. One is shared values and beliefs. The other is predictable behavior in an environment where deviant behavior is penalized. In general, the scientific community has such shared values and beliefs with regards to the rigor of the scientific process (Merton 1973; Jasanoff 1987). Further, most scientists see colleagues, with a few exceptions, behaving according to the norms of science and have confidence in mechanisms—such as replication and peer review—that disclose and sanction unethical behavior. However, these bases of trust among scientists are not always shared by those engaged in global change politics (Jasanoff 1987). In fact, since issues of global change are so complex, a large nonexpert community judges the risks and

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benefits associated with an issue based on the trust it has in the institution or process (Earle and Cvetkovich 1995; Siegrist et al. 2000).

Trust in an assessment, as in any process that relies on deliberation among multiple individuals, requires that the process be seen as both fair and competent (i.e., legitimate and credible) (Habermas 1970; Renn et al. 1995). Because trust conflates fairness and competence (Habermas 1970), the terms "credibility" and "legitimacy" are used instead throughout this report to distinguish the two sources of trust (Ravetz 1971; Clark and Majone 1985; Social Learning Group 2001a). Legitimacy implies that those who have a view on the issue, and those who will be affected by decisions that emerge from the process, have the opportunity to have a say in the process either directly or through a third party whom they trust. Further, it requires that the process allows all views to be given serious consideration, with the outcomes determined by thoughtful deliberation under rules seen as acceptable to all participants. Credibility implies that those who have knowledge relevant to the issues at hand participate in ways that allow their knowledge to influence the discussion, either through their direct participation or through consideration of their work.

The following questions provide guidance for global change assessments to achieve credibility and legitimacy:

- Who has interests at stake in the outcomes of the assessment process?
- What kind of expertise is required to understand the issues being considered?

Process assessments, impact assessments, and response assessments differ considerably in who has interests at stake, what kinds of expertise are relevant, and who has that expertise. Thus, implementation of the requirements for a legitimate and credible assessment will differ across the three types of assessments.

Process Assessments

Process assessments describe the state of the natural world as we understand it, the global change of interest, and its natural and anthropogenic causes (for detailed definition see Chapter 2). They are not intended to provide policy options, and therefore strive to avoid analysis of values, such as benefits, costs, or risk preferences. This simplifies the task of achieving credibility and legitimacy compared to impact assessments that inevitably consider value judgments and trade-offs. Science has strong norms for how to carry out deliberations about the state of knowledge, so it is relatively easy, in principle if not in practice, to conduct a credible process assessment

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(Jasanoff 1987). Rigorously adhering to the science and the established rules regarding the inclusion of peer-reviewed or non-peer-reviewed material helps to ensure credibility. These preestablished norms are undoubtedly one reason the committee finds that many process assessments have been conducted successfully. Over the years, the knowledge and practice of conducting this type of assessment have been developed and refined by a core of experienced scientists and assessors, and have been successfully applied to multiple generations of stratospheric ozone assessments (WMO 1986a, 1990a,b, 1992, 1995, 1999, 2003, 2007) and the Intergovernmental Panel on Climate Change (IPCC) Working Group I (WG I) assessments (IPCC 1990a, 1995a, 2001a).

A well-established and successful model for process assessments has emerged that involves the following key elements:

- Getting a critical mass of the world's most respected scientists in the relevant fields to participate;
- Ensuring broad participation and sponsorship;
- Having an intensive, science-focused process of deliberation that is of such high quality that it attracts the number and quality of participation required and produces reports that can serve as authoritative scientific references in the field;
- Urging the process to provide clear consensus evaluations of the state of knowledge on key policy-relevant questions, to the extent the underlying knowledge base allows;
- Writing clear, compact summaries with the involvement and consent of the scientific author teams; and
- Disseminating the summary messages prominently and consistently.

Even in the case of process assessments, it might be difficult to achieve the perception of legitimacy and credibility. Indeed scientists and other experts who participate in an assessment may have a different perspective on its legitimacy than others who expect that the outcome will affect their interests but are not intimately involved in the process (Jasanoff 1987). In practice, process assessments will be perceived as legitimate only if the intended target audience has ways of ensuring that the relevant questions are addressed and that scientific controversies of concern have been resolved to its satisfaction and by a process it considers legitimate (Jasanoff 1987). In the case of climate change in particular, many political actors realize that the conclusions drawn by process assessments, such as IPCC WG I, shift the momentum of policy decisions that are highly consequential for their actions. In turn, some actors external to the scientific community are increasing skeptical of these process assessments (McCright 2000; McCright and Dunlap 2003). If the sole purpose of the process assessment is to reach

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a scientific consensus, it might need to achieve credibility only among the scientific community (Social Learning Group 2001a). However, if there is substantial political interest in the outcome of a process assessment, then it will need to achieve credibility and legitimacy among a broader audience whose concern is not with the science per se, but with the policies that may be adopted as a result of scientific conclusions. It is commonplace in environmental disputes for arguments that are logically about values (e.g., weights to be given to the costs, benefits, and risks associated with climate change, biodiversity loss, or ozone depletion) to be framed in terms of disputes about facts (Dietz et al. 1989; Dietz 2001). Thus, the factual content of a process assessment may be criticized even if the underlying concerns are about policy choices, and thus more about values than about facts.

A major challenge for process assessments over the next decade may be in enhancing credibility and legitimacy among those who feel their interests are affected by the outcomes of these assessments. The IPCC process, in particular, is an attempt to develop legitimacy among a wider stakeholder group for all of the working group products, including that of WG I.

Impact Assessments

Impact assessments have been much less successful in achieving credibility and legitimacy than process assessments (Parson et al. 2003; Moser 2005). Impact assessments, which characterize the impacts of environmental change and human and natural systems, need to be perceived as credible and legitimate among the broadest audience. To achieve scientific credibility, all the rules of a process assessment apply. However, the expertise needed to "get the science right" in an impact assessment is typically broader than for process assessments.

Impact assessments also must be credible and legitimate to those who will be affected by the global change being analyzed, the policies implemented to address that change, or both. Because impacts manifest themselves within localities, economic sectors, and ways of living, highly contextualized "local" knowledge—that is, knowledge about the places, sectors, or activities that may experience impacts—is essential to an accurate analysis. The literature provides substantial guidance for local and regional participation (Cohen 1997; Kasemir et al. 1999, 2003; Harremoës and Turner 2001; Van Asselt and Rijkens-Klomp 2002; Toth 2003). Some assessments, such as the Millennium Ecosystem Assessment (MA) and the U.S. National Assessment of Climate Change and Variability, have made extensive efforts at incorporating local knowledge, and their efforts were at least partially successful (Morgan et al. 2005). Nevertheless, effectively incorporating local knowledge in impact assessments remains a challenge.

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Another major challenge for attaining legitimacy and credibility in impact assessments of global scope is the relative lack of experience in ensuring adequate and legitimate participation at that scale. In particular, ensuring equity in participation between developing and developed nations is a significant challenge, necessitating capacity building for local knowledge to be incorporated in a fair and competent way (Jager et al. 2001).

In the case of impact assessments, achieving legitimacy and credibility is further complicated because, unlike process assessments, they usually require value analysis, that is, some weighting of costs, benefits, and risks as they are visited across various populations. Just as the assessment must be competent with regard to the scientific "facts" it addresses, it must be competent with regard to the values deployed in analyzing trade-offs and options (Dietz 2001, 2003). Although systematic procedures for assessing values and risk preferences and aggregating them are available, they are complex and none are without controversy.

Response Assessments

Response assessments focus on reducing human drivers of the environmental change or their impacts. There is a logical coupling between response and process assessments, mediated by the scenarios of emissions or other anthropogenic perturbations that are used to drive projections of future environmental change in the process assessments. Process and response assessments together have a logical structure, considering human and natural factors along with potential human interventions, that is parallel to the complete structure of impact assessments. But, whereas the human and natural factors cannot be separated in impact assessments, they can be separated at the boundary between process and response assessments. This separation is usually done by using scenarios that describe how human driving forces will unfold over time. Such scenarios become the mechanism that crosses the boundary between process and response assessment. Scenarios provide process assessments with a set of possible futures that are plausible even if a response assessment does not attempt to assign probabilities to future states of the world. This ability to separate process and response assessments by the use of scenarios makes both process and response assessments much easier to conduct successfully than impact assessments, albeit at the cost of resting the process assessment on "what if" scenarios rather than detailed analysis of social system responses. As with impact assessments, the involvement of stakeholders is essential for the success of response assessments, but in this case, who the stakeholders are and how to involve them are starkly different.

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Technology Assessments: A Special Type of Response Assessments

The parties interested in and affected by the choice of technologies are composed primarily of industries and others that develop and deploy technologies, regulators who enforce decisions, and those in academic and other research institutions who develop technology. Achieving a legitimate, and in some cases legal, technology assessment brings additional challenges regarding proprietary information and the possibility of giving some participants competitive advantage (Parson 2006).

A further challenge in technology assessments is thinking broadly about the implications of its conclusions. Some technological choices have widespread societal and environmental consequences. Sectors of the economy, regions, and lifestyles can all be changed substantially by technological choices, producing both winners and losers. Some have argued that technological choices are as consequential as or more consequential than what are seen as standard political decisions.

In general, if the assessment's conclusions will lead to decisions that have relatively minor impacts, it may be sufficient to achieve credibility among those who work directly with the technology (Clark et al. 2001). For example, technological solutions to the ozone problem required mainly finding an alternate coolant for refrigeration or an alternate non-CFC-emitting production process for foams. Because these solutions only impact the industry sectors involved and not the public at large, they can be considered as having minor impacts. On the other hand, in the climate change debate, consideration of switching to nuclear power to reduce greenhouse gas emissions has potentially major impacts on the public. Thus, given the broader societal implications of the choices, a broader community involvement may be necessary to ensure legitimacy.

Integrated Assessments

As discussed in Chapter 2, there are multiple approaches to and multiple definitions of integrated assessments (Parson 1995; Weyant et al. 1996; Rotmans and Dowlatabadi 1996). Some refer to the production of a synthesis report that includes social, biological, and physical science components and that is based on loosely coupled multidisciplinary analysis (Parson 1995). Another definition is restricted to the development and use of models that explicitly link the dynamics of social, biological, and physical systems (Ravetz 1997, 2003). Over time, the latter, more tightly coupled form of integrated assessment has become more common.

Even the most thoroughly integrated assessments often neglect issues that are of considerable importance in decision making, such as equity (Morgan and Dowlatabadi 1996). While it is important to analyze equity,

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there are practical difficulties in conducting such analyses in assessment processes that require broad consensus.

First, the available methods for analyzing equity, such as distributionally weighted cost-benefit analyses, require assumptions about the weight that should be given to risks, benefits, and costs visited on one group versus another. Such weights are value judgments, and it is difficult to develop consensus on value judgments in assessments (Moser and Dilling 2004; Moser 2005). This problem occurs even when formal methods are not used. Simply identifying equity issues requires agreement about what dimensions of inequality should be given consideration (region, gender, ethnicity, social class, etc.), a complex and often contentious problem itself.

The degree and nature of the integration is a design decision, ideally made with specific reference to the users and purpose of the assessment. If an integrating structure is designed, it is possible to ensure that broad-scale assessments can continue to be developed, while at the same time enhancing the relevance in individual applications where many resource decisions are made (Schneider 1997; Schneider and Lane 2005).

Integrated assessments provide opportunities to address multiple spatial scales (local to global) and multiple stresses relevant to an environmental change. Indeed, the U.S. National Assessment *Climate Change Impacts on the United States* (NAST 2001) called for a more integrated approach to examining impacts and vulnerabilities to multiple stresses. For example, assessment of the impacts of climate change on the health sector was clearly limited by the lack of knowledge of the integrated system. Changes in vector-borne diseases (e.g., dengue fever delivered by mosquito populations) could clearly be tied to climate change and variability; however, there were many other environmental factors that also controlled the distribution of these diseases (e.g., the importance of land use on host distribution, waste products that impact water and air quality, human social systems). A National Research Council (NRC) workshop Understanding and Responding to Multiple Environmental Stresses (NRC 2006) notes that integrated assessments are required when the impacts and decisions are place-based (i.e., specific to a locality or region) but the drivers of impacts are also drawn from a much larger scale (e.g., climate change). The link between large-scale drivers and place-based contexts and a focus on multiple stresses also increase the ability to put knowledge to work by connecting to stakeholders and decision makers in the location where the decisions are relevant. This "nested matrix" approach is a model to be further explored because it combines the strategic advantages of a broad-scale assessment while allowing a number of detailed case studies that are more useful to local decision making.

In recent years, considerable attention has been given to effective methods for engaging decision makers and the public in the process of

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integrated assessment in ways that enhance the quality and integrity of the science (Cohen 1997; Kasemir et al. 1999, 2003; Harremoës and Turner 2001; Van Asselt and Rijkens-Klomp 2002; Toth 2003). Not all assessments need to be fully integrated, although there are many benefits to working toward an integrated approach, including a greatly enhanced potential to be policy relevant. In general, an integrated assessment is justified when the problem itself is multidimensional, as is the case with most environmental problems. Having the appropriate disciplines—including both physical, biological, and social scientists—involved in an assessment is critical for both scientific and political credibility. Social scientists are especially critical for structuring the problem and communicating uncertainties and risks (Tol and Vellinga 1998; Van Asselt and Rotmans 2004). For example, climate change can be explained in terms of physical processes that are connected to the wide variety of human activities that give rise to greenhouse gas emissions, leading to impacts on society. Understanding the various links in the chain and their interconnections is an extremely complex undertaking involving inputs from a multitude of disciplines. In addition, social science perspectives can be critical for adequately incorporating uncertainty into models (Van Asselt and Rotmans 2004).

The rationale for an integrated assessment is that the separation that differentiates process, impact, and response assessments from each other is ultimately artificial and may lead to science that is less robust than might be ideal. Responses depend on real and perceived impacts; they affect the processes driving global change and consequently alter the impacts; finally, responses themselves have impacts. Rational decision making should take account of the full range of these interactions. Of course, as Levins (1966) has noted, models are always simplifications, so integrated assessments must make decisions about how to simplify. Linked assessments tend to maintain much of the complexity of individual assessments, at the cost of less than full articulation and harmonization. In contrast, fully integrated assessments tend to maximize articulation and harmonization, but at the cost of simplifying. Both of these strategies can be useful, but the trade-offs need to be weighed carefully in advance. For some decisions, the detail contained in linked assessments, but often lost in fully integrated assessments, is essential. However, the limited articulation of linked assessments means that some critical feedbacks are either not considered or considered only qualitatively.

Despite the importance of integrated understanding for decision making, methods of integration, whether nested matrices or fully integrated models, are at an early, yet rapid, stage of development (Morgan and Dowlatabadi 1996; Schneider 1997; Tol and Vellinga 1998; Van Asselt and Rotmans 2003; Schneider and Lane 2005) and deserve further development, including model comparisons. The Energy Modeling Forum (*http://www.stanford.edu/group/*

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EMF) and the newly formed Integrated Assessment Society (*http://www.tias-web.info/*) are taking laudable steps in this direction.

SCIENCE-POLICY INTERFACE: BALANCING CREDIBILITY WITH SALIENCE

The appropriate interface between science and policy is frequently debated and requires deliberate negotiation at the onset of each assessment process (NRC 1983; Jasanoff 1987; Cash and Moser 2000). The interactions between scientists and policy makers in assessments can assume different forms, ranging from efforts to isolate the scientific community from the policy-making process via boundary organizations such as the National Academies, to highly institutionalized collaboration and deliberative processes between both groups, such as congressional hearings. Regardless of where along the spectrum the science-policy interface falls, each community "must maintain its self-identity and protect its sources of legitimacy and credibility" (Farrell et al. 2006).

Especially careful boundaries are necessary between the authorizing body (i.e., those requesting the assessment) and the assessment participants. While the authorizing body needs to be involved in the framing of the goals and scope of the assessment to ensure that the most salient questions are addressed (NRC 1996), legitimacy and credibility suffer when it is perceived that they control the assessment process (Jasanoff 1987; Cash and Moser 2000). At the same time, isolating scientists from the authorizing body too much is likely to result in a loss of salience (NRC 1996). Therefore, negotiating this boundary is a balancing act between achieving credibility, legitimacy, and salience (Jasanoff 1987).

Based on its deliberations and input from scholars and practitioners of assessments, the committee concludes that an explicit boundary is critical throughout the process, but most importantly during the review stage. A key determinant of credibility is the quality control applied in an assessment. Quality control is defined as the procedures designed to guarantee that the "substantive material contained in the assessment report agrees with underlying data and analysis, as agreed to by competent experts" (Farrell et al. 2006). Different criteria are used to define what an expert opinion is (e.g., that which is published in peer-reviewed journals or is subject to repeated reviews). For assessments that undergo government review, it is critical that the expert participants retain a "veto right" regarding the scientific content of the report (Watson 2006).

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ENGAGING STAKEHOLDERS

Stakeholders include all interested and affected parties in an assessment process: those who commission the assessment, the experts who participate in the process, those who are affected by the pertinent environmental change, and those in a position to take actions in response to the assessment's results. The four types of assessments—process, impact, response, and integrated—have inherently different kinds of stakeholders who can usefully be engaged. The appropriate stakeholders may be scientists, decision makers, politicians, resource managers, the public, and so forth. Even those without the technical expertise to engage in the assessment process may still perceive themselves to be stakeholders because they are affected by the outcome, particularly in the case of impact assessments.

In public processes, in which broad stakeholder engagement is desirable, it usually is beneficial to cast the net as widely as possible. Minimizing the risk of offending groups and sectors by failing to invite their participation is often more important than limiting the cost associated with borad public engagement (Jacobs 2002; Jacobs et al. 2005). The credibility and legitimacy of public processes, such as assessments, often rest on the perceptions created by the engagement process, particularly regarding the process of selecting participants and the transparency thereof (NRC 1996; Jacobs et al. 2005; Watson 2006).

Engaging the public and local knowledge poses a special challenge because meaningful participation in assessments may require some familiarity with the scientific or technological issues at hand. Public involvement can be facilitated if individuals are already organized in nongovernmental organizations (NGOs) or other organizations, which can send representatives to participate in the dialogue. Such was the case for the Arctic Climate Impact Assessment (ACIA), where the local population was organized in a tribal consortium (Corell 2006).

When engaging stakeholders, there is always tension between the need to establish balance among interest groups, ensure credibility of results, allocate sufficient time and resources to support a broad engagement effort, and encourage ownership in the process by participants. Based on the committee's collective experience, significant benefits and impacts often result from engaging stakeholders in the assessment process, rather than relying simply on disseminating the final assessment product. Engagement throughout the process builds trust between individuals and between categories of users; results in broader understanding of multiple perspectives; builds a shared knowledge base that may be useful in other applications; and develops a network of relationships that will prove useful in the future (NRC 1996; Jacobs 2002).

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Private-Sector Stakeholders

Engaging private-sector stakeholders can lead to effective response assessments, but it has proven especially challenging (Parson 2006). Private-sector stakeholders have different information needs and modes of engagement than public-sector participants. Their world view and "decision context" may be more constrained in time, interest, and resources than those of other participants. Therefore, carefully designed, sector-specific engagement strategies may be required to ensure their participation (Semans 2006). The private sector may be critical in ensuring that the assessment has the desired salience for decision makers because of their ties with economic viability or vulnerability, their interest in cutting-edge scientific advances, and their political connections (Parson 2006). There are benefits in sector-specific assessments as well as cross-sector assessments, depending on the goal of the engagement.

Industry participants often have access to the best information about relevant technologies. In this case, a successful assessment needs to identify and include top technical experts, but should also consider very carefully their and their employers' motivations in participating. While individuals and firms may want to contribute, they operate under market and competitive pressures that compel them to consider what they might gain from the participation (Parson 2006). Therefore, assessment organizers may need to provide incentives for industry to participate. Most often, response assessments are initiated before regulatory policies to mitigate the environmental risk are in place, with a goal of evaluating whether technology options are feasible and sufficiently cost-efficient that regulatory policies can be adopted without major economic impacts. Asking industry representatives to participate energetically in these sorts of assessments and to disclose information openly is comparable to asking potentially affected industries to provide a green light to impose regulations (Parson 2006).

Despite the complexity of private-sector engagement, there are many situations in which the private interests of participating individuals and their firms can be sufficiently aligned with the public interest to obtain high-quality assessments of technical options (Parson 2006). The three general situations that are conducive to private-sector involvement are:

1. When some firms perceive that, because of their technical skills or competitive positioning, they might gain an advantage from a regulatory response to the issue;
2. When firms judge that an environmental issue has become so serious that regulation is inevitable, and they think that participation might provide them with better information, influence over regulatory details, or a step ahead of competitors; and

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3. When challenging regulatory requirements are imminent or already enacted, and firms judge that participating in an assessment process can help them solve the resultant technical problems they already face to meet this regulatory burden (Parson 2006).

Such assessment processes work best, because they not only give high-quality technical assessments of present capabilities, but they actually advance present capabilities because the participants solve problems by applying technologies within their organizations at the same time as they are assessing the status and feasibility of the technologies. This was the case for the Technology and Economic Assessment Panel (TEAP) of the stratospheric ozone assessments.

The following questions require careful consideration during the framing of the process if a response assessment wants to harness the expertise of private-sector stakeholders: What are the appropriate breadth and form of the assessment process? Can such assessments be conducted under official auspices, or should they be convened ad hoc? How should the technical questions at issue and the assessment process be defined to protect against unwillingness to disclose technical information to regulators and regulatory advocates, unwillingness to disclose technical information to competitors, and hijacking of technical deliberations to serve interests of individual firms or technologies?

Stakeholder Capacity Building

Capacity building to develop a common language and technical understanding among assessment stakeholders can greatly enhance the effectiveness of assessments. Not all stakeholders will be familiar with the science or the policy context of a particular assessment. Decision makers may not be conversant in the relevant science. Scientists and other expert participants may need assistance in communicating effectively with experts from other disciplines and with other stakeholders. Meaningful engagement with the public may also require a degree of capacity building and iterative learning between the "experts" and the public to arrive at a shared set of facts and a focus on issues that are of clear importance to the stakeholders (Farrell et al. 2001; NRC 1996). It is imperative that the engagement be viewed as a "two-way" communication, since the "experts" often have much to learn about impacts, vulnerability, perceptions, and local knowledge of systems (NRC 1996; Jacobs 2002).

Capacity building may involve a broad range of activities, including joint fact-finding efforts, joint development of goals and objectives for specified assessment activities, training in the use of specific decision-support tools, and use of various engagement strategies such as focus groups to

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identify leaders within sectors and regions who are interested in science translation (Jacobs 2002). The cost of capacity building in terms of time and resources is often underestimated and is a frequent reason for delays in public processes (Farrell et al. 2001; Parson et al. 2003). Indeed, the NRC (2004) noted the need for the U.S. Climate Change Science Program (CCSP) to build capacity in newer areas of its program, including decision-support activities. Nonetheless, efforts focused on capacity building and decision support can ensure salience, credibility, and legitimacy and improve the transition between research and applications, particularly for assessments that address adaptive capacity and resilience in the context of global change (Morgan et al. 1999; Moser and Dilling 2007).

Investments in capacity building can have payoffs in multiple areas, including expanding the informed audience for the assessment, contributing to future assessment effectiveness, expanding the ability of decision makers to act on scientific information, equipping participants with new knowledge in assessment methodology and tools, and building a scientific community that is more sensitive to needs and concerns of the broader society. In some cases the value of the assessment process, which may involve considerable time commitments on the part of participants, might not be immediately apparent. Thus, additional effort may be required to communicate the benefits and to structure the questions and process such that they are relevant to the participants the assessment aims to engage.

CONNECTING SCIENCE WITH DECISION MAKING

Effectively linking science with decision making entails challenges beyond those of negotiating the appropriate science-policy interface and effectively engaging stakeholders. Decision makers often point to the lack of salience of assessments for their decision-making process due to a mismatch in the scale or timing of the information available (Jacobs et al. 2005). In other instances, the complexity of the issue presented is too great to assist in the decision-making process (Scheraga and Smith 1990). In addition, available policy analysis tools (e.g., cost-benefit analysis) are sometimes inadequate for global change issues such as climate change (Morgan et al. 1999). Because of the uncertainty and complexity associated with issues such as climate change, decision makers require analyses that allow them to assess the accuracy of the available information and the potential effectiveness and risk associated with certain policies (Scheraga and Smith 1990; Jacobs et al. 2005).

Decision-oriented analyses and tools could be developed as part of a larger-scale process, impact, or response assessment, to connect the information with the appropriate decision framework (Scheraga and Smith 1990). The Regional Integrated Science Assessments, sponsored by the

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National Oceanic and Atmospheric Administration, provide some examples of tools that have successfully helped decision makers use climate information (*http://www.climate.noaa.gov/cpo_pa/risa/*). For example, a forecast evaluation tool was developed by the Climate Assessment for the Southwest to assist water resource managers in evaluating the forecast skill of previous seasonal climate forecasts (Jacobs et al. 2005). This tool fosters the application of climate forecast information available in typical process assessments to decisions such as reservoir management, agricultural crop and irrigation decisions, stocking decisions on ranch lands, and flow management for habitat preservation. In Michigan, a team has developed tools to make climate forecasts useful to decision makers in agriculture and tourism (*http://www.pileus.msu.edu*). When integrated models are tailored to particular decision-making processes or scales, the complexity of the issue is reduced and the feasibility of a useful integrated assessment is increased. In fact, programs such as the Regional Integrated Science Assessments illustrate how regional assessments can be nested within a national or global assessment. A need for further development of decision-support tools for global change assessments has been pointed out by many authors, particularly at the regional scale (Scheraga and Smith 1990; Easterling 1997; Morgan et al. 1999; Jacobs et al. 2005). A greater investment in developing such tools will significantly enhance the ability to seamlessly apply assessment findings to the decision-making process.

The ability to successfully develop tools for decision makers requires familiarity with the institutional, economic, and political context within which decision makers operate. A wide range of such policy-analysis and decision-support tools are needed and are being developed. Many such efforts are far too complex and beyond the scope of what assessments such as the IPCC or the CCSP could support meaningfully. Nevertheless, programs such as the Regional Integrated Science Assessments serve as successful examples of regional assessments that allow context-specific, salient information to be developed. Such local and regional efforts can be nested within a national or global assessment. The concept of a nested matrix for assessments involves developing a general framework to identify trends and vulnerabilities at the national scale on an ongoing basis, allowing for prioritized, focused, integrated assessments of specific sectors and regions to illustrate the richness and context of impacts at the scale that resource decisions are normally made. To some degree, this approach was developed within the MA and the National Assessment of Climate Change Impacts.

REVIEW PROCESS

Most global change assessments to date have well-established review mechanisms, incorporating some combination of expert, public, and gov-

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ernment review. Some assessments, such as TEAP, have not included a formal review process because all of the major stakeholders were already involved in preparation of the report and because they included proprietary information. Stratospheric ozone assessments are peer reviewed, but do not undergo public review because the scope of the issue is limited and the perception of legitimacy in this process by all major stakeholders has been established over time.

Effective review processes increase credibility by allowing many individuals to evaluate the veracity of the report and increase legitimacy by involving a larger range of stakeholders (Edwards and Schneider 2001). A transparent process for review is especially important (Edwards and Schneider 2001; Watson 2006). The following questions are helpful for establishing the guidelines for review of an assessment product:

- Will there be an expert review only, or also a stakeholder, government, and public review?
- How will reviewers be selected?
- Who coordinates the review process?
- How will responses to review comments be handled?
- Will reviewer comments and responses be made public?

To address the risk that experts involved in the assessment process might promote an agenda or their own research, the review process can be designed to include a balanced group of reviewers, incorporating varied viewpoints and expertise from outside the field of science being assessed. Legitimacy in the process often can be enhanced by setting up an independent body of respected individuals to function as a neutral broker between the reviewers and the experts involved in the assessment process.

CONSENSUS BUILDING

Dissenting voices among assessment participants can negatively impact perceptions of the legitimacy of the assessment process and can even detract from its credibility if the dissent is not addressed in a rigorous and transparent fashion (Edwards and Schneider 2001). Ideally, assessment leaders will manage the process such that either a consensus can be found, or the dissenting conclusions can be incorporated into the process. For example, differing views can be explained by inherent uncertainties of the state of knowledge or by alternative interpretations of available information. Assessments are more likely to be effective if they have clear guidelines agreed upon by participants from the outset and explicit treatment of dissenting views.

Given that process assessments rely on the latest scientific knowledge available, dissenting conclusions in these types of assessments are more

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easily addressed. The scientific method provides norms regarding the evidence required to draw certain conclusions (Jasanoff 1987; Edwards and Schneider 2001). Impact assessments, however, must rely in part on value judgments, which can create a greater challenge regarding the resolution of differing opinions. In this context, a fair and transparent treatment of all sides of the argument, with detailed explanations of how each conclusion is drawn, will allow the assessment users to make their own value judgment based on the information presented.

CHARACTERIZING UNCERTAINTY

Characterizing uncertainty can represent a challenge in assessments, in terms of determining what sorts of uncertainty information would be useful for decision makers as well as developing quantitative or qualitative measures of uncertainty (Johnson and Slovic 1994; Patt and Schrag 2003). While there is evidence that decision makers have an aversion to ambiguity (VanDijk et al. 2004), uncertainty is unavoidable in many decision-making contexts. Once decision makers understand that they are operating in an uncertain environment, they typically prefer that the conclusions of an assessment be accompanied by a description of the level and source of relevant uncertainties (Johnson and Slovic 1994). It is also important to manage expectations about reducing uncertainties because some of these uncertainties will not be resolved for decades if at all.

A range of approaches have been employed for characterizing uncertainty related to environmental change, including standard statistical techniques, model-based sensitivity analysis, expert judgment, and scenario development. It is difficult, if not impossible, to objectively and quantitatively define uncertainty for many of the complex issues related to climate change. In cases where quantitative techniques can not be applied, scientists and others preparing an assessment often are forced to choose between providing no uncertainty estimates or developing and implementing qualitative approaches, typically based in part on expert judgment and consensus (Morgan and Keith 1995). The committee concludes that, in cases where uncertainty estimates have been requested, it is appropriate for the practitioners of the assessment to make every effort to accommodate that request by using expert judgment.

Objective, Quantitative Methods for Assigning Uncertainty

Statistical theory provides a detailed and robust framework for defining the uncertainty in a parameter derived from a dataset, for example, the statistical or probability distribution of possible results about a mean derived from repeated sampling of a population. Although such methods

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may be applicable for characterizing a single climate parameter (e.g., the average temperature at a given location) and whenever possible should be used, they are often not applicable and can even provide misleading results in climate change assessments.

One limitation of statistical approaches is that, in climate change assessments, many of the parameters of interest are derived from space-borne platforms that require complex analysis and/or state-of-the-science technology. Statistical methods only provide an assessment of the random error in the measurement; they do not address systematic errors that can arise from artifacts in the instrumentation, the methods used to reduce the raw data, or both. If systematic errors in the measurement are present, a statistical measure of the uncertainty from random error will underestimate the real uncertainty and can lead one to be overly confident in the veracity of the result.

A case in point is the estimate of mid-tropospheric temperature trends from satellite and balloon measurements. For many years, analyses of these data indicated that mid-tropospheric temperature trends were inconsistent with surface temperature trends, even after accounting for statistical uncertainties (NRC 2000). These results were interpreted by some to mean that the current warming was not due to greenhouse gas warming and were widely debated in the lay media as well as the scientific literature. Subsequent analysis uncovered errors in the methods used to translate the satellite and balloon measurements into temperature values. After correcting the data processing methods, the apparent inconsistency in the mid-tropospheric and surface temperature trends disappeared (CCSP 2006).

Another reason quantitative statistical methods are often not applicable is that inferences and conclusions about future climate change (e.g., the influence of human activities) are based on a complex synthesis and analysis of many parameters, factors, and lines of evidence. Quantitative and fully objective estimates of uncertainty in these cases are not feasible.

Model Simulations and Uncertainty

Many aspects of climate change science are based on model simulations. These range from estimates of the global warming potential of greenhouse gases, which can depend on model estimates of the atmospheric lifetime of a gas, to predictions of future temperature and precipitation trends. The most widely adopted approach to estimating uncertainty in model predictions is sensitivity analysis, in which the range of probable model outcomes is assessed using a series of model realizations with a range of values for the various inputs. Both the sensitivity to specific model parameters (e.g., how clouds or air-sea exchange are represented) and to different scenarios for future greenhouse gas emissions can be tested in this manner. For this

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method to be reliable, it is important that the set of sensitivity or scenario runs accurately portray existing uncertainties (Morgan et al. 2005). In most applications of sensitivity analysis, an upper and lower bound to the model prediction are obtained but not a probability distribution for the range of results.

Incorporating the model simulation into a Monte Carlo algorithm can provide a statistical estimate of uncertainty with probability distributions (Metropolis and Ulam 1949; Cubasch et al. 1994; Robert and Casella 2004). However, Monte Carlo applications within the framework of a climate assessment present two problems. First, Monte Carlo analysis requires knowledge of the probability distributions (i.e., statistical uncertainty) of the parameters under consideration and such distributions are rarely well defined for the reasons discussed above. Second, climate models are computationally expensive and Monte Carlo requires an often unfeasibly large number of model realizations to obtain statistically meaningful results. Investigators have attempted to address the latter by reducing the number of simulations required by using algorithms that identify the most critical regions of the parameter space (Tatang et al. 1997).

Another approach that yields statistical estimates of model uncertainty with probability distributions is the so-called direct sensitivity analysis technique, in which the uncertainty of each parameter is incorporated into the underlying differential equations of the model. Overall model uncertainty is then directly calculated by the model itself. One version of this approach—the Direct Decoupled Method—has been used in air quality modeling (Russell and Dennis 2000), but, to the best of the committee's knowledge, it has not been used for climate modeling. The advantage of direct sensitivity analysis is that it eliminates the need for multiple model simulations. However, like Monte Carlo, it requires knowledge of the probability distributions of parameters under consideration.

The approaches described above can, if carried out properly, yield a statistical measure of the uncertainty in the model output. However, the results can be misleading because the methods used are based on the assumption that the model or models completely describe and account for all relevant processes. If the models have unknowingly omitted an important process, the actual results can lie far outside the uncertainty range predicted. For example, the stratospheric ozone models failed to predict the appearance of the Arctic ozone hole because they did not include important heterogeneous chemical reactions.

Expert Judgment

In many global change assessments that evaluate potential outcomes in complex systems, the characterization of uncertainty for policy makers must

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rely on qualitative metrics arrived at through a consensus of experts. For example, qualitative metrics (such as "virtually certain," "likely," etc.) are used in the IPCC assessment. For these metrics to be useful, all participants, including policy makers, must share and accept the meanings intended by the qualitative metrics. Other formal approaches to developing expert consensus, such as the "Delphi method" and techniques for drawing conclusions based on a range of expert judgment, have been developed (De Groot 1970; Oalkey 1970; Watson and Buede 1987; Morgan et al. 1984).

Scenarios

Scenario analysis can be a useful tool for developing insights on the importance of key uncertainties and where additional research may have the greatest payoff. Where there are legitimate differences in opinion over the true state of the world, the scenario analysis approach can help clarify the importance of alternative assumptions and resolve seemingly intractable conflicts by illustrating a range of potential outcomes. However, scenario development is information intensive and requires data that are internally consistent. Such information may or may not be readily available. Further, scenarios are frequently confused with predictions of future conditions, so communication of appropriate ways to interpret them is essential.

A STRATEGIC COMMUNICATION PLAN

If an assessment's scientific findings are effectively communicated, understood, and accepted by the target audience, there is a greater chance that optimal policies and decisions will be undertaken to address the environmental challenges analyzed in the assessment. Ideally, the communication strategy involves a multifaceted approach: getting to know the target audience, recognizing its information needs, and actively engaging its members in the process (Moser and Luganda 2006). In designing a communication strategy, the assessment team should try to analyze and respond to the interests, motivations, receptivity, knowledge base, barriers, and resistance of different target audiences (Moser and Luganda 2006; Moser and Dilling 2007). The basic objective is to stimulate individuals to think about problems, risks, and solutions, and thereby to influence policies, decisions, and behavior.

The communication process should be active during the entire assessment, and not solely be designed around the report dissemination. Effective assessments have a comprehensive, multifaceted communication strategy right from the start, encompassing an analysis of the target audiences, alternate modes of reaching and engaging them, desired responses (e.g., policy decisions, legislation, technological innovation, standards, international

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treaties), and appropriate follow-up activities. Further, the communication and outreach do not end with publication of the assessment report, but are an ongoing, dynamic, and iterative process of interaction with stakeholders, media, academe, and the public.

The audiences targeted for communication efforts may differ through the assessment process and may be influenced by the issues themselves and by desired responses to the assessments. At different stages, the audience will comprise those who commissioned the assessment, those who are affected by the environmental problems it addresses, and those who can influence relevant legislation, business policies, and new product or technology development. Thus, target audiences may include government policy makers at national, state, and local levels; business decision makers; scientists and technical experts not initially involved in the assessment but relevant for solutions (e.g., engineers, economists, epidemiologists); affected communities (e.g., indigenous peoples in the Arctic); NGOs; and the general public. Each audience will differ in their degree of receptivity, knowledge, values, self-interest, and capacity to act (Johnson and Slovic 1995; Moser and Dilling 2007).

In addition to the target audience, the communication plan often needs to consider appropriate intermediaries to engage in the process (e.g., the media, prominent opinion leaders, consultants, educational institutions). These intermediaries help translate the assessment results for the target audience and are commonly the most sophisticated users of the assessment products. However, it is important to consider the potential for some intermediaries to distort or select facts in order to either exaggerate or downplay the impacts. If such intermediaries are too closely engaged in the dissemination process, the credibility and acceptance of the assessment might be hampered, stimulating resistance to action based on its conclusions.

Modalities for communication and outreach extend beyond the printed page, including informal meetings and consultations, seminars and dialogues, public forums, selected working groups, interviews and news conferences, television, Internet, and CDs. Different types of publications and communication activities will be appropriate for different audiences. The MA, the stratospheric ozone assessments, and the ACIA are examples of assessment processes that produced an array of different publications and communications for different audiences—from policy makers to business to the general public.

Effective assessment reports are concise, accessible, visually attractive, and user-friendly; investment in the writing and review process is critical. In terms of substance, it is important that the information provided is relevant to the needs of the most important stakeholders. For example, the global-scale information about climate change provided by the IPCC may not fully meet the local, regional, and short-term needs of stakeholders. More

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generally, an assessment providing mainly global abstractions may fail to motivate decision makers at regional and local levels.

The characteristic complexity of the science and the range of scientific uncertainties add to the communication challenge (Johnson and Slovic 1995; NRC 1996; Johnson 2003; Patt and Schrag 2003). Indeed, there may be an inherent conflict between a scientist's penchant for exactitude and the effective presentation of an environmental assessment to a nontechnical audience. The complexity of the science is often daunting, encompassing projections of cumulative, minute changes in multiple variables for long future time frames; theoretical models and scenarios; complicated assumptions about risks; and the multidisciplinary nature of the subject matter.

Conscious and imaginative efforts to simplify language, tables, and scenarios can make them more understandable (Johnson and Slovic 1994, 1995). Creative use of easy-to-understand charts, tables, graphs, and photographs can add significantly to a report's effectiveness and impact, particularly by enhancing the assessment's interest for media and other intermediaries. Many of the visual components of IPCC reports (e.g., the tangle of multiple-scenario trajectories) are virtually incomprehensible to nonexperts, in contrast to the attractive visual displays in the ACIA reports. Accessibility is also enhanced when both the basic report and other documentation are made available on the web in usable form and, if appropriate, translated into key languages.

A summary is possibly the most crucial element of the written assessment product and an effective dissemination process, especially if it is concise, unbiased, clear about assumptions and uncertainties, free of jargon, and relevant to the various needs of decision makers. Different types of summaries may be appropriate for different audiences. For media and the general public, for example, the summaries can be briefer, more colorful, and less technical, while still scientifically impeccable; ACIA offers useful examples (ACIA 2004). For business use, technology and product-oriented summaries, as in TEAP, are appropriate, especially when industry experts are involved in their preparation (UNEP 1991a, 1994a, 1998a, 2002a). The scientific assessments under the Montreal Protocol have used "Twenty Questions and Answers about the Ozone Layer" effectively to communicate to a wide range of nontechnical audiences.

In sum, the most effective communications strategies are not based on a single encyclopedic report, however exemplary its scholarship. Rather, it will comprise frequent consultations with stakeholders throughout the process; media outreach, engaged dialogues, meetings, and forums with key audiences; and a diversity of publications and pamphlets tailored to multiple audiences. Effective publications strategies are flexible, varying with different audiences and objectives, and producing products that differ, for example, in the degree of complexity, in policy relevance, in local or

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regional focus, in basic education, and in technical emphasis. Such effective communication strategies can be expensive, requiring that budgetary provisions for communication are appropriate to the degree and scale of the desired communications outreach. The budgetary costs can be justified by analyzing in advance the potential benefits of effective communications for a successful assessment outcome.

SUMMARY OF GUIDANCE FROM THE LITERATURE

The scholarly literature on assessments cited above provides a rich and growing body of information on how to create a credible, legitimate, and salient assessment process. These characteristics are enhanced through a process of thoughtful deliberation, which is fair and competent, in which all reasonable views are given serious consideration. Four elements are central:

1. Engagement builds legitimacy and credibility. Who is at the table and whether they participate in two-way communication define perceptions of fairness and balance in point of view.
2. A transparent review process and a deliberate effort to promote consensus increase legitimacy and credibility. Transparency in handling critical comments is particularly important in minimizing perceptions of bias or imbalance.
3. Deliberate and consistent methods of treating and communicating uncertainties add credibility and salience. Regardless of method (statistics, sensitivity analysis, scenario development, or expert judgment), each measure must be defined and communicated in a consistent manner.
4. A deliberate and active communication strategy instituted at the onset of an assessment process enhances the value, credibility, and legitimacy of the process and products. An effective communication plan recognizes the nature of the audiences, including their interests, receptivity, and knowledge base, as well as any barriers to communication.

The difficulty in incorporating these four key elements depends on the nature of the assessment. Process assessments have a well-worn path for success, which includes incorporating a critical mass of experts, ensuring broad participation, focusing intensively on a specific science issue, developing consensus through a state-of-the-science evaluation, instituting authoritative review, and offering a clear summary of the results. As a result, process assessments are less likely to be subject to criticism for their credibility or legitimacy, unless the science topic is associated with the perception of great political importance.

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In contrast, assessments that focus on impacts or responses present greater challenges. In each case, achieving credibility and legitimacy requires involving a broader set of stakeholders, often with more specific interests and biases. Further, the assessment outcomes are much more likely to involve analyses that depend on assigning values; hence, it is more likely that they will generate a diversity of opinions that impact legitimacy and credibility. It is important that impacts and response assessments be designed in a manner that accepts the challenge of broadening the participation and the level of communication, while also recognizing that there is still much to be learned about how to conduct these types of assessments successfully.

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4

Case Studies of Global Change Assessments

The careful examination of past assessments can provide important lessons to steer future efforts. This committee was asked to look at past assessments that had objectives similar to those of the U.S. Climate Change Science Program (CCSP), evaluate the strengths and weaknesses of the selected past assessments, and identify lessons learned that might guide future CCSP assessment activities. The committee could not conduct an exhaustive review of all past assessments, so it limited itself to assessments with objectives similar to the CCSP and where adequate information was available. Because the charge was to provide advice on how to conduct future U.S. assessments, the analysis focuses on issues relevant to the decision-making context in the United States. It is important to acknowledge, however, that the literature shows that assessments of global environmental change are viewed differently in other countries and are less important for decision makers in developing countries than in industrialized countries (Biermann 2006). Also, both global environmental problems and their solutions are perceived and assessed differently by industrialized and developing countries (Gupta 1997).

This chapter summarizes the committee's review of the eight assessments listed in Table 4.1. For each, the committee describes the science and policy context and stated purpose of the assessment, examines design issues and other elements, and then provides an analysis of strengths and weaknesses. Upon closer examination, the committee found that each of the assessments evaluated has strengths and weaknesses: none is a failure but none is without limits. This provides the variation in form and outcome

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TABLE 4.1 The Eight Assessments Included in the Comparative Analysis

Assessment	Brief Description
Stratospheric Ozone Assessments	Prior to the 1987 Montreal Protocol, there were several national (including NRC) and international assessments analyzing ozone-depleting chemicals and the state of the stratospheric ozone layer (e.g., WMO 1982, 1986a). Following the treaty, a system of expert advisory panels was established to periodically assess the atmospheric science of the ozone layer (WMO 1990a,b, 1992, 1995, 1999, 2003, 2007), the impacts of ozone loss (UNEP 1991a, 1994a, 1998a, 2002a), and the technology and economics of alternatives to ozone-depleting chemicals (UNEP 1991b, 1994b, 1998b, 2002b).
Intergovernmental Panel on Climate Change (IPCC)	IPCC analyzes scientific and socioeconomic information on climate change and its impacts, and assesses options for mitigation and adaptation. It provides scientific, technological, and socioeconomic findings to the Conference of the Parties to the United Nations Framework Convention on Climate Change (IPCC 1990a,b,c, 1995a,b,c, 2001a,b,c).
Global Biodiversity Assessment (GBA)	GBA provides a synthesis and analysis of available science on biodiversity to support the work of the UN Convention on Biological Diversity (GBA 1995).
National Assessment of Climate Change Impacts (NACCI)	Undertaken in response to the Global Change Research Act (1990) to evaluate the impacts of climate change on the United States (NAST 2001).
Arctic Climate Impact Assessment (ACIA)	Primary objectives were to evaluate and synthesize knowledge and indicators of climate variability, climate change, and ultraviolet radiation in the region; to assess possible impacts of future changes in climate and radiation; and to provide reliable information to both governments and peoples of the region to support policy-making processes (ACIA 2004).
Millennium Ecosystem Assessment (MA)	MA was designed to answer questions fundamental to various UN conventions dealing with natural resource issues, in particular the consequences of diverse environmental changes on the functioning of ecosystems, including their continuing capacity to deliver services essential to human well-being (MA 2005a,b).
German Enquete Kommission on "Preventive Measures to Protect the Earth's Atmosphere"	The Enquete Kommission brings scientists and policy makers together to assess the importance and consequences of stratospheric ozone depletion and climate change for Germany among other dimensions of global environmental change (Enquete Kommission, 1988, 1991).

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TABLE 4.1 Continued

Assessment	Brief Description
Synthesis and Assessment Products by the U.S. Climate Change Science Program (CCSP)	The 21 assessment products were designed to address the mandate of the Global Change Research Act, by considering science and policy issues spanning the range of topics addressed by the CCSP. The first product, on temperature trends in the lower atmosphere, was released in April 2006 (CCSP 2006).

that is essential in comparative case analysis. Of the eight assessments examined as case studies, the committee selected two of the examples—the National Assessment of Climate Change Impacts (NACCI) and the CCSP Synthesis and Assessment Products—because they are the assessment efforts of the agencies of the U.S. federal government sponsoring this report. The NACCI is an interesting example of a large-scale assessment based largely on regional and sectoral analyses, as well as an interesting experiment in stakeholder participation and multisponsor coordination. Because most of the CCSP Synthesis and Assessment Products are still under way, that assessment effort is considered last, as a "work in progress." The the Stratospheric Ozone Assessments, Intergovernmental Panel on Climate Change (IPCC) assessments, Global Biodiversity Assessment (GBA), and the Millennium Ecosystem Assessment (MA) were selected because they are the largest and best known global assessment efforts and thus provide the most extensive experiential base from which to learn. The committee also examined the recent Artic Climate Impact Assessment (ACIA) because it was a regional rather than a global assessment (albeit for a large, international region), and because it attempted to learn from the other cases examined here and deployed some innovative procedures based on that learning. The German Enquete Kommission was included because it provides a different model for linking science and decision makers than any of the other assessments, and thus provides a point of comparison on that critical issue.

STRATOSPHERIC OZONE ASSESSMENTS

Concerns about anthropogenic destruction of stratospheric ozone first appeared in the 1960s, initially based on emissions of nitrogen oxides and hydrogen oxides from aviation, bombs, and rockets. Subsequently, ozone loss caused by chlorofluorocarbons (CFCs) was first proposed by Molina and Rowland (1974). Early research validated the key qualitative points in their hypothesis, but more authoritative and quantitative resolution required large research advances in reaction kinetics, atmospheric trace-gas measure-

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ments, stratospheric modeling, and computational power. In the 1980s the scientific foundation for these concerns was solidified and then amplified by the discovery of the Antarctic ozone hole, leading to an intensive two-year effort to explain this observation. Atmospheric observations and laboratory studies eventually confirmed ozone-depleting substances as the cause of the ozone hole and also linked these substances to the global stratospheric ozone loss (WMO 1990a).

After articulation of the CFC risk, multiple assessments were conducted through the 1970s and early 1980s, organized by the U.S. National Academy of Sciences (NAS), the U.S. National Aeronautics and Space Administration (NASA), the U.K. Department of Environment, the United Nations Environment Programme (UNEP) and World Meteorological Organization (WMO) Coordinating Committee on the Ozone Layer, the European Commission, and others. These were all conventional, small-panel assessments. The U.S. (NAS and NASA) and U.K. assessments were populated by scientists from their own nations. However, none of these efforts had the global legitimacy and credibility required to support an international agreement. Eventually, the separate efforts converged, with increasingly broad participation, into a single, authoritative international assessment process.

The first two international ozone assessments (WMO 1982, 1986a) were produced independently of and prior to the Montreal Protocol. Participation in ozone assessments was broadened greatly by the 1985 assessment, which included hundreds of scientists from many countries and secured cosponsorship by WMO, UNEP, the U.K. Department of the Environment, and the German Umweltbundesamt, as well as three U.S. government agencies (WMO 1986a). This document provided the scientific basis for the 1987 Montreal Protocol.

As a result of major changes in international politics and support from U.S. industry for international controls, during 1986-1987, negotiations led to the first Montreal Protocol, which represents an unprecedented international agreement to cut production and consumption of CFCs by half and to freeze the consumption of halons. Early assessments were mostly atmospheric process assessments with a couple of attempts to assess impacts or response options (such as technological alternatives to ozone-depleting chemicals). Under the Montreal Protocol, the following consistent structure of three parallel periodic assessments evolved: (1) an assessment of atmospheric processes (WMO 1990a,b, 1992, 1995, 1999, 2003, 2007); (2) an assessment of the effects (human health, agricultural, ecological, materials, later added air quality) (UNEP 1991a, 1994a, 1998a, 2002a); and (3) an assessment of the technology and economics of reducing the use of ozone-depleting substances by the Technology and Economics Assessment Panel (TEAP) (UNEP 1991b, 1994b, 1998b, 2002b).

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Since the initial negotiation of the Montreal Protocol, there has been a rapid series of reductions of major ozone-depleting substances, led by private industry, with parallel tightening of regulatory restrictions on multiple occasions. Consequently, world emissions of ozone-depleting substances have been reduced significantly, and the only remaining issues are methyl bromide, developing-country phase-out schedule for hydrochlorofluorocarbons, and exemptions.

Establishing Clear Rationales and Appropriate Institutional Structures. Leadership of the three assessment panels has been relatively stable over time, with a core group of experts leading the assessments since 1981 and the impacts process and TEAP assessments since 1989. It is these leaders, particularly for the process assessments and TEAP, who provided the interface between the policy process and the assessment panels. Through dialogue with the Parties to the Protocol, the assessment panels have focused on key policy questions, ensuring the relevance of results. The assessment panels then organized chapter lead authors to develop detailed report outlines and time lines.

Although funding was provided under the Montreal Protocol for travel support for developing-country participants in the assessments, individual governments provided support for the participation of their scientists as well as for publication of the documents. Individual companies provided support for their experts to participate. Except for the inclusion of scientists and technical experts from developing countries, there was no focused effort at capacity building.

Designing and Scheduling Assessment Activities. This assessment used the approach of providing an authoritative summary of the state of scientific research, addressed primarily to scientists working in the field. However, its scale and prominence, as well as its technical authority, comprehensiveness, and detail, brought coherence to the public debates over stratospheric ozone science that had never been attained before. In part because of the widely recognized contribution of the 1985 ozone assessment (WMO 1986a), the Montreal Protocol included authorization to establish similar expert assessment panels. Although, with few exceptions, the prior assessments had been exclusively atmospheric science assessments (process assessments), the Montreal Protocol authorized the establishment of four expert assessment panels addressing: atmospheric science (process assessment), impacts of ozone depletion (impact assessment), technology, and economics. The last two were subsequently merged to a single response assessment.

The protocol mandates the assessments to be repeated in time to be available to the Parties in advance of their meetings. Over the last two decades, these assessments have been conducted every four years. According

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to their original mandate these assessments are only supposed to update the Parties with the latest and newly available information, not provide a comprehensive review. Nevertheless, these assessments continue to be conducted at a large scale despite the fact that the main objective of these assessments, particularly the process assessment, has been fulfilled. The added value of each new assessment seems to be relatively small compared with the effort and resources committed to the process.

Involving the Scientific Community and Other Relevant Experts. The 1985 stratospheric ozone assessment helped develop the approach referred to here and elsewhere as a process assessment. The assessment engaged a critical mass of highly respected scientists worldwide in an intensive process of critically reviewing current advances and later in an intensive scientific peer review. This approach established credibility and legitimacy.

The impact assessment panel followed a model similar to that of the process assessment, but at a smaller scale. This panel lacked the same accumulated experience, and faced more difficult problems in that it had to consider multiple areas of impacts with non-overlapping fields of expertise. It also often worked with information from less mature fields.

The technology assessment panel merged with the economics panel to form the TEAP, which adopted a strikingly different model. Organizers recognized from the start that success depended on private sector technical participation. Therefore, they designed the process to be easy and attractive for private-sector representatives to participate by focusing on solving problems identified by the private-sector and assessment organizers. As a result, confidential working groups of high-level technical experts from firms facing similar problems (e.g., how to reduce the use of CFCs in producing insulating foams) were convened; a rapid, informal, results-oriented process was established; and the process or product was not peer-reviewed. Instead of peer review, organizers trusted that participants with overlapping levels of expertise and a balance of material interests would police each other for self-serving claims. In almost all cases, the working groups were able to reach consensus without a formal process, simply by deliberating with internal norms of evidence-based argument and basic confidence in each other's good faith. In a very few cases, groups were unable to come to agreement and included dissenting or minority text in their reports. The inclusion of experts from the firms directly affected by the phase-out of ozone-depleting substances, along with academic and government experts, ensured relevance, credibility, and legitimacy for the process. The committee considers the assessment processes conducted under the Montreal Protocol's TEAP as representing the single area of conspicuous success in this regard.

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Communicating Scientific Knowledge Accurately and Effectively. Communication of the results of the ozone assessments was simpler than was the case for many other global change assessments because the decision makers and key stakeholders were well defined and limited in number. Inclusion of most of the scientists directly involved relevant research in the process and impact assessments and of the technology leaders in the TEAP ensured communication with scientists and companies. Adequate communication of findings to regulators was ensured by distributing the reports to government decision makers and following up with presentations by scientists leading the processes at international meetings and before government bodies. Environmental organizations and the media helped communicate the results to the general public.

The presentation of assessment conclusions has grown increasingly sophisticated over time. The 1985 stratospheric ozone assessment did not even have an executive summary whereas recent assessment reports have carefully prepared summaries, viewgraphs, talking points, and associated nontechnical publications, such as "Common Questions about Ozone," that summarize current knowledge in commonsense terms and implicitly address any current attempts to mislead or obscure the consensus. These assessments have continued to exercise substantial influence over policy discussions, influencing multiple revisions of the treaty.

One important flaw in the stratospheric ozone assessments is that there has been no consistent treatment of uncertainties across the assessment panels or even within individual panels. Perhaps the most important advance in avoiding the political pitfalls associated with characterizing uncertainties was the development of a measure called "effective equivalent stratospheric chlorine" (EESC, a weighted combination of anthropogenic chlorine and bromine) that can serve as the key metric for monitoring progress in ozone protection. After establishing the links between ozone-depleting substances and ozone depletion and between ozone depletion and health and environmental impacts, the scientific assessment panel used the level of EESC above a designated threshold as a measure of risk. With this metric, they could present policy options in the form of EESC curves illustrating a series of possible regulatory options.

Guiding Plans for Future Activities. The character of the most important questions related to ozone has shifted over time, as the policy regime and the state of knowledge have advanced. First, it was critical to demonstrate authoritatively the seriousness of the issue by projecting the magnitude of future ozone loss under a wide range of emissions scenarios without control (WMO 1986a). Then, the emphasis shifted to presenting more precise quantitative projections of future impacts of specific alternative decisions that policy makers were considering. And recently, the major objective has

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been to track observable environmental consequences of actions taken. This evolution demonstrates that past assessments under the Montreal Protocol have successfully guided the next generation of assessments to address the shift in issues and relevant questions.

Creating Valued Products. The process assessments produced by the first panel have exercised decisive influence over the policy debate and made key contributions to the changes in certain policy actors' positions. The 1985 assessment of the scientific understanding of stratospheric ozone depletion was essential to breaking ten years of policy deadlock and led to concrete international action in 1986 and 1987 (Benedick 1998; Parson 2006). Although the impact assessment was important for reasons of completeness, there is no evidence that the substance of these products ever mattered in policy debates, either before or after the Montreal Protocol.

The TEAP assessments achieved unprecedented success in providing high-quality technical advice to the Montreal Protocol parties regarding the available technical alternatives. In addition, these assessments also served to promote problem solving in deploying alternatives and to disseminate information among relevant industry sectors. In other words, TEAP has not only provided highly credible assessments of present technical capabilities, but repeatedly helped to advance those capabilities. Like the atmospheric science assessments, the technical judgments of the TEAP have exercised substantial influence over policy decisions.

Key Strengths and Weaknesses of the Stratospheric Ozone Assessment. Compared to many aspects of global change, the stratospheric ozone issue is confined to a relatively small number of stakeholders. This simplifies the process of developing salience, credibility, and legitimacy of the assessments. The stability of the structure and leadership of the panels ensured improvements in efficiency of the process and value of the products. Inclusion of scientists from laboratories around the world who were actually involved in research on the issues developed the necessary credibility and legitimacy. The skill of the leadership in communicating the results ensured relevance and recognition.

Strengths:

- All panels enjoyed extreme autonomy, with leaders of each panel having unusual authority over the participation, process, and specific mandate covered, while still maintaining a close enough relationship with decision makers to ensure the content would be relevant.
- The process assessment benefited from excellent leadership, which was effective in forcing often reluctant participants to render synthetic

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scientific judgments, even when going beyond what is already published in the literature.

- The TEAP addressed key decisions of private-sector actors regarding research, development, and investment.

Weaknesses:

- The process assessment continues to be conducted in a comprehensive manner despite that its mandate is only to provide an update of new findings after early assessments succeeded in demonstrating the seriousness of the problem. Each new assessment has made a smaller incremental contribution to the decision-making process.
- In the TEAP process, the interests of key industrial participants gradually diverged from the remaining questions of concern to policy makers. The remarkable early successes of this process were based on the precise alignment of these interests. Now it has become harder to attract critical masses of participation to address the remaining implementation questions.
- The TEAP process succeeded for so long that it has attracted backlash from those seeking to reimpose political control on the process.
- Exclusion of economic or cost judgments in considering technical options initially proved to be a strength because it allowed the process to get started. However, it limits the ability to generalize the model, because technical assessments on other issues cannot necessarily ignore costs by assuming that rapid innovation will make them low enough.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

The IPCC was established in 1988 by the WMO and the UNEP to conduct assessments of the scientific basis for human-induced climate change, its likely impacts, and opportunities for adaptation and mitigation. Several international meetings that took place in 1985-1988 (Bulkeley and Betsill 2003; Torrence 2006), along with a series of unusual weather events in the summer of 1988 (Paterson 1996), helped move climate change to the central stage and served as the impetus to initiate the IPCC. The idea behind the IPCC was grounded both in the experience of the Montreal Protocol negotiations and in TEAP. Since its inception, IPCC has initiated four rounds of assessments, the last being completed over the course of the year 2007 (IPCC 1990a,b,c, 1995a,b,c, 2001a,b,c).

The IPCC assessments have been important for informing formal negotiations of an international climate change treaty, a process which started in December 1990. The United Nations Framework Convention on Climate Change (UNFCCC) was adopted at the Earth Summit, held in Rio de Janeiro in May 1992; it was subsequently signed by more than 150 nations

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and entered into force in March 1994. The UNFCCC established a goal of stabilizing greenhouse gases at a level that would prevent dangerous anthropogenic interference with the climate system (United Nations 1992). In 1997, despite some opposition, participants established a framework for negotiating the Kyoto Protocol. This protocol was signed at the Conference of the Parties 3 held that year in Kyoto and would enter into force with the ratification of at least 55 countries, in February 2005. The specific rules for its implementation were agreed at Conference of Parties 7 in 2001, and post-Kyoto negotiations have been very contentious.

Establishing Clear Rationales and Appropriate Institutional Structures. The stated goal of the IPCC is to "assess the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change, its potential impacts and options for adaptation and mitigation." Within IPCC, however, there is debate about whether its role is to review and assess existing literature, to conduct integrated assessments, or both.

Major decisions of the IPCC are made by a plenary group of government representatives. The plenary elects a chair, three vice-chairs, two co-chairs for each of three working groups and a task force on greenhouse gas emissions inventories, and six vice-chairs for each of the three working groups. These 30 elected chairs and vice-chairs make up the IPCC bureau. The bureau oversees the organization and preparation of IPCC products including assessments, special reports, and technical papers. Each working group is supported administratively by a technical support unit; the overall bureau is supported by a secretariat.

Designing and Scheduling Assessment Activities. IPCC's work is divided among three working groups. Working Group I assesses scientific information on the climate system and the potential for human-induced climate change. Working Group II assesses scientific, socioeconomic, and technical information on the vulnerability of humans, ecological systems, and socio-economic sectors to climate change, and evaluates information on their adaptive capacity and adaptation practices and options. Working Group III assesses scientific, technical, and socioeconomic information on options to mitigate climate change. In addition, the Task Force on National Greenhouse Gas Inventories provides guidelines for methodologies and practices for preparation of the inventories.

The structure, including chapter outlines, and work plans for each assessment is prepared by the bureau and approved by the plenary. A team of lead authors is assigned to each chapter of each assessment, with one or two coordinating lead authors, usually representing a developed and a developing country. These teams are accountable for organizing the work

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of their team and delivering the chapter to the Working Group Bureau. Ultimately the ownership and responsibility for a chapter lies with its lead author team. For each working group, a team of lead authors, consisting of coordinating lead authors and additional experts, prepares a technical summary based on the underlying chapters. The technical summary of each Working Group then provides the basis for preparation of a draft summary for policy makers. Once all three Working Group reports have been accepted and their summaries for policy makers approved, the IPCC bureau and selected coordinating lead authors prepare a synthesis report with the objective of providing a comprehensive and coherent summary of the three reports.

These assessments are conducted on a regular interval and are expected to produce a report every five years. The next generation of assessments is initiated shortly after the completion of the previous due to the extensive effort and time required to conduct such a comprehensive effort. Thus, it has become almost a continuous process engaging a significant size of the research community and stakeholders placing a considerable strain on the participants' time.

Involving the Scientific Community and Other Relevant Experts. Governments and other organizations are involved in nominating lead authors. Based on the scientific and technical expertise and credentials of each of those nominated, the bureau selects lead authors for each chapter of the assessments. These authors can be from government, academia, industrial organizations, or environmental organizations and are expected to represent their individual knowledge and expertise, and not a preconceived organizational perspective, in the preparation of the assessments.

When the IPCC was first established, participation was strikingly unbalanced. In the second IPCC assessment report for instance, "the percentage of Southern Hemisphere coordinating lead authors, lead authors, and contributing authors in working groups ranged from 5.1 percent (for Working Group I) to 25 percent (for Working Group III)" (Biermann 2006). The IPCC has taken different actions to increase the participation of scientists from developing countries and to remove obstacles that impair their involvement (e.g., current rules require each working group to be chaired by one developed- and one developing-country scientist). This has been perceived as a successful "learning" of an assessment institution (Biermann 2006). Nevertheless, lack of financing and resources still constrains the research and time that scientists from developing countries can devote to assessment activities (Biermann 2006). Engaging and training the next generation of scientists to participate in these assessments might also become a challenge due to the difficulty for young scientists to justify the opportunity cost to advancing their research. Thus, ensuring a continuity in highly quali-

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fied participants who understand the assessment process might become a challenge.

The IPCC has established norms in regards to what type of information can be included. For the process (Working Group I) and impact (Working Group II) reports only peer-reviewed literature may be included. The response assessment (Working Group III) relies primarily on peer-reviewed literature but may also use some "gray" literature, such as working papers, government reports, theses, and technology-specific information. The gray literature must be accepted by the lead authors and must be available on request by reviewers of the assessment.

IPCC reports are reviewed in a three-step process. A first draft is peer-reviewed by experts in government, academia, industrial organizations, or environmental organizations. In response to the review, a second draft is prepared that is distributed for a second round of expert and government review. The lead authors then prepare a final draft of the full report and a technical summary, as well as an initial draft summary for policy makers that is distributed to governments for final review. The participating governments then meet in plenary session for each Working Group report to accept the full report and technical summary and approve the summary for policy makers. Coordinating lead authors for each chapter participate in this meeting to ensure that the approved version of the summary for policy makers is consistent with the full report and technical summary. The synthesis report—including the technical summaries and summaries for policy makers from all three Working Groups along with an overall summary for policy makers that synthesizes information across the Working Groups—is subsequently approved in a plenary session of all three Working Groups.

The IPCC shows that setting rules and firewalls is crucial to establish clear rationales and clear institutional structures. Yet the political oversight and negotiations that are part of the IPCC process have raised some issues of credibility within the scientific community. It is important that these negotiations honor both the need for ownership by the governments and the need for scientific credibility.

Engaging the Potential Users of Assessment Products. A primary audience for the IPCC assessment are national governments, and government representatives are deeply involved in the process. All major decisions are made by government representatives at the plenary—for example, on IPCC's principles, procedures, and structure; mandate of working groups and task forces; work plan; and budget. Early in the process, government representatives are involved in selecting the leaders of each Working Group. In addition, government representatives as well as other organizations can nominate lead authors for each chapter. There are opportunities governments and other users of the assessments to participate in the review of the reports. Finally,

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at the end of the process, once again the primary users—governments—step in and have a critical role in reviewing the summary for policy makers.

Communicating Scientific Knowledge Accurately and Effectively. The presentation of IPCC findings has grown increasingly sophisticated over time. The third assessment (IPCC 2001a,b,c), for example, contains well-prepared summaries, viewgraphs, and nontechnical publications for the lay public. To enhance the communication of IPCC scientific findings, major documents are translated into all six United Nations languages (Biermann 2006). The reports and summaries are distributed to participating governments, and are available on the IPCC web site, and paper copies can be ordered.

The IPCC provides clear guidance about how its authors should evaluate and communicate uncertainties and confidence in findings. Defining a common approach and language across all IPCC reports is challenging and has not been fully achieved yet because the nature of the information used in the natural sciences (WG I) and in the social sciences (e.g., WG III) is quite different. The IPCC insists that approaches to uncertainties be considered at an early stage of the process, and that all plausible sources of uncertainties be considered using a systematic typology of uncertainty (unpredictability, structural uncertainty, value uncertainty). In the third assessment report (IPCC 2001a), levels of confidence, which are used to characterize uncertainty that is based on expert judgment as to the correctness of a statement, an analysis, or a model, are stated with reference to the following scale: very high confidence means at least a 9 out of 10 chance to be correct; high confidence: at least 8 out of 10; medium confidence: 5 of 10; low confidence: 2 of 10; very low confidence: less than 1 out of 10. The statement of likelihood, which refers to a probabilistic assessment of some well-defined outcome having occurred or occurring in the future, is based on the following language: "virtually certain" refers to a probability of occurrence greater than 99 percent; "very likely," to more than 90 percent, "likely," to more than 66 percent; "about as likely as not," to 33 to 66 percent; "unlikely," to less than 33 percent; "very unlikely," to less than 10 percent; and "exceptionally uncertain," to less than 1 percent.

Creating Valued Products. It is reasonable to say that IPCC assessments exercise substantial influence over policy debates and discussions, despite the fact that the IPCC does not develop decision-support tools per se. Instead, it evaluates the state of the art and reviews and synthesizes the results of analyses applying such tools. The assessments produced by the IPCC are referenced by many in the public sector and are widely accepted as a credible source of information on climate change. It also seems to be successful at reaching multiple target audiences. Although the IPCC is

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viewed as a credible and legitimate information source on climate change for many regional and local decision makers, it has not been successful yet at providing information at more regional scales. Some experts in the developing world think that the IPCC still neglects southern socioeconomic issues, which restricts the salience of the information offered by the report (Biermann 2006).

Key Strengths and Weaknesses of the IPCC. Building on the experience of the stratospheric ozone assessments, the assessment process of Working Group I is somewhat more developed than that of Working Groups II and III. The Working Group I model is especially effective for conducting assessments in disciplinary fields that are well delimited, that is, in which the key questions are well posed and recognized by both scientists and policy makers. In particular, the reports produced by Working Group I have effectively showed the significance of climate change. However, the magnitude of IPCC assessment activities is growing significantly. Rather than stating scientific progress or identifying new issues, IPCC reports tend to be comprehensive documents demanding a significant time commitment from lead authors. Given that past assessments have been effective and the substantial burden placed on the scientific community with every additional comprehensive assessment, it seems appropriate at this point to consider alternate approaches. For example, the process could be shortened and made more efficient by focusing on how new data support or contradict previous conclusions.

Working Groups II and III have also made important contributions to the discourse on climate change; however, there are both less scholarly understanding and fewer models of effective assessments to build upon in areas such as climate change impacts and vulnerability, where the disciplinary boundaries and key questions are more diffuse. In particular, Working Group II has been successful in reaching international audiences, but less so in local and regional audiences, due to the lack of regional information included (Corell 2006). Indeed, impact assessments often are most effective if they start with the regional scale and then scale up to subregional and global scales (Watson 2006).

Strengths:

- Well-developed organizational structure.
- Strong ties to stakeholders.
- Widely considered a credible source of information.
- Attempts to present different points of views.
- Addresses multiple audiences.
- Well-defined role for scientific community and governments.
- Excellent multifaceted communication process.

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Weaknesses:

- Coordination among working groups needs to be strengthened.
- Scheduling of products is on a predetermined timetable without consideration for the rate at which new knowledge becomes available, which in some cases is slower than the rate at which assessments are produced.
- Assessment effort places tremendous burden on the scientific community at the cost of conducting new research.
- Treatment of uncertainty is uneven.
- Ensuring continuity might become an issue unless younger scientists are recruited and trained in conducting assessments.

GLOBAL BIODIVERSITY ASSESSMENT

Negotiations for a convention on biological diversity began in 1988 during a UNEP-led meeting of experts on issues of biological diversity. The Convention on Biological Diversity (CBD) opened for signatures in 1992 and entered into force in 1993. Its mandate is to conserve, sustainably use, and share the benefits of biological diversity. The CBD did not have a formal scientific assessment as an underpinning, but instead the framers worked with ad hoc working groups of legal and technical experts (Bernstein et al. 1993). Although the convention did not call for assessment activities, the GBA was initiated after the convention and was crafted to provide such a scientific foundation; it was completed in 1995 (GBA 1995). Because the GBA was not formally mandated by the Conference of the Parties of the CBD, it had only informal ties to the convention.

Establishing Clear Rationales and Appropriate Institutional Structures. The GBA grew out of a recognized need to provide a scientific foundation for the CBD. Although it was administered by UNEP, it did not have a formal connection to the CBD process; hence it lacked a clear mandate, which proved to be an important flaw in the design (Watson 2006). The project document was characterized by a lack of detail. As the first effort of its kind to assess the global state of the biodiversity and the health of global ecosystems, no model was available to guide this undertaking. Limited funding also played a role in the planning process.

Designing and Scheduling Assessment Activities. The budget for the GBA was limited given the scope of the mandate. The lack of funding restricted the numbers of meetings available for planning, report preparation, and dissemination. In addition, it limited the size of the support staff in Nairobi, which hampered the facilitation of many stages of the process.

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Involving the Scientific Community and Other Relevant Experts. The GBA followed the IPCC procedures for selecting international experts. It underwent an extensive review process, involving 1,100 scientists and experts in the preparation and review. The assessment was restricted to include only peer-reviewed information. Yet, scientists and experts in the developing world claim that this assessment neglected developing countries' perspectives on issues such as intellectual property rights (e.g., Northern patents on basmati rice and neem-tree products) or the safety of genetically modified organisms transferred into developing countries (Biermann 2006; Gupta 2006).

Engaging the Potential Users of Assessment Products. The principle target audience was the country representatives to the Conference of Parties for the CBD. The potential users of this assessment were not directly engaged during the process. Instead, reports were delivered to them at the end of the process. Two thousand copies of the main report and 4,000 copies of the summary for policy makers were distributed. These publications were sent to all contributors and distributed to participants in the relevant CBD Conference of Parties. The summary for policy makers was also sent to capitals and to UN organizations. The results were not available on the web.

Communicating Scientific Knowledge Accurately and Effectively. The communication effort mainly involved publication and dissemination of a final report. The report is quite lengthy: even the summary for policy makers is 56 pages. The large size of these documents has been cited as an impediment to their use. A planned popular version of the report never materialized, probably due to funding limitations.

Guiding Plans for Future Activities. The GBA was the first comprehensive analysis of the science of biological diversity. In many ways it provided valuable lessons and set the stage for other biodiversity and ecosystem assessments. One review of the GBA said that the process had "a lot of hidden value in . . . stimulating research, framing questions and in linking experts around the world" (Kaiser 2000). There are now efforts to mount a new biodiversity assessment that would overcome the limitations of this initial effort (Loreau et al. 2006).

Creating Valued Products. The summary volume has been valued by the scientific community as an extensive and comprehensive review of the state of the knowledge but was not formally accepted by the CBD or incorporated into its work. The disconnect stemmed from the lack of authorization of the process by the CBD, as well as tensions caused by an independent international group giving advice to a formal, country-driven process where

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property rights are a major concern. The assessment did not provide any policy analysis or evaluate the information in any decision-making context. Thus, the global approach failed to recognize the need for assessments at the national or regional scale of greatest relevance for most of the actions required to carry out the convention.

Key Strengths and Weaknesses of the GBA. In many ways, the lessons learned from this assessment have contributed to and guided the second effort to assess global biodiversity and ecosystem functions undertaken by the MA.

Strengths:

- First attempt at a global assessment that covered all of the many dimensions of biological diversity.
- High scientific credibility due to the involvement of world's leading scientists.

Weaknesses:

- No authorizing environment and hence a lack of government acceptance.
- Limited budget hindered outreach (e.g., no web posting of products) and substantive interaction among working groups.
- Products not very "accessible" to policy audience.

NATIONAL ASSESSMENT OF CLIMATE CHANGE IMPACTS

The U.S. Global Change Research Act (GCRA) of 1990 calls for a periodic assessment of the state of climate science, including the potential impacts of climate change on natural resources and human well-being in the United States. NACCI was officially requested by Dr. John H. Gibbons, then director of the President's Office of Science and Technology Policy, and was charged with addressing questions centered around (1) the role of climate change in exacerbating or ameliorating existing environmental stresses, (2) priority research needs to better inform policy makers, (3) coping options, (4) resource planning and management options in the face of uncertainty, and (5) improving our ability to adapt to climate change and variability.

The National Assessment (NAST 2001) began with a series of workshops involving diverse stakeholders. A National Assessment Synthesis Team (NAST), composed of experts from industry, academia, government laboratories, and nongovernmental organizations (NGOs), provided overall guidance on scope and process. The assessment revolved around the development of a series of regional teams covering the entire United States and sector teams for water, health, forests (ecosystems), and agriculture, as well

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as two focused efforts on coastal regions and native peoples. The regions and sectors bounded the scope of the assessment. The NAST designated common climate datasets for use by the regional and sector teams as the broad context for their more targeted analysis. These common datasets consisted of historical climate data for the nation (1895-1995) and two climate model outputs (1895-2100) representing a range of climate sensitivity to increased greenhouse gases. The results from each region and sector were incorporated into a synthesis report by the NAST.

Establishing Clear Rationales and Appropriate Institutional Structures. The President's science adviser provided specific, well-articulated questions that framed the National Assessment as specifically mandated by the GCRA. The NAST was established as an independent committee under the Federal Advisory Committee Act (FACA) with substantial authority to guide the assessment process. The NAST was well supported by representatives from each of the agencies participating in the U.S. Global Change Research Program (GCRP). The five sector teams and the teams in 20 regions across the United States each had team leaders. The 20 regional teams were grouped into nine megaregions, which provided the input to the NAST's synthesis report. The coordination among the various regions, sectors, and the NAST was facilitated by the National Assessment Coordination Office. However, the support for the regional and sector teams was dependent on the willingness of individual agencies to provide funding carved out of existing budgets. As a consequence, some teams were poorly funded, received no funding at all, or were funded very late in the assessment process. The lack of integrated cross-agency support and funding influenced the timing and nature of the regional and sector reports.

Designing and Scheduling Assessment Activities. The National Assessment was designed as a tiered process, extending over a three-year period, with the NAST providing initial guidance on climate scenarios, scope, involvement of stakeholders, and expectations. Communication was facilitated through frequent meetings and through a structure of individual NAST members serving as liaisons to the various teams. The NAST worked to entrain the results from regions and sectors, to develop common formats, and to address gaps and weaknesses. The GCRP was late in complying with the mandate of the 1990 GCRA, which called for an assessment delivered to Congress no less than every four years, whereas the process did not formally start until 1997. Therefore, the NAST and the sector and regional teams worked in tandem. The process would have benefited substantially by a phased or nested approach, in which the climate scenarios were debated with inputs from sectors and regions, and then established first, along with guidelines for the sectors and regions.

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One of the controversial aspects was the use of climate models that were not produced by U.S. scientists (MacCracken et al. 2003). The U.S. models available at the time did not include some of the necessary features: for example, no U.S. model had 200-year-long simulations with the spatial resolution and features required to examine impacts on agriculture, ecosystems, and water. The design of the National Assessment was intended to be an iterative process between the NAST and the regional and sectoral teams. Ideally, the initial phase of establishing protocols and universal datasets for use by the regional and sectoral teams would have been followed by an extended period of work at the regional and sectoral levels. The NAST would have then integrated and synthesized the regional and sectoral efforts after they were completed and vetted. Unfortunately, time constraints forced the synthesis team to work simultaneously with the regional and sectoral teams.

Involving the Scientific Community and Other Relevant Experts. The NACCI worked diligently to involve a wealth of experts, from a variety of institutions, spanning the full range of topics from climate change to regional information to sector knowledge. The NAST was established by the National Science Foundation as an independent committee under FACA and consisted of experts from academia, industry, government laboratories, and NGOs. Each regional and sectoral team involved experts with knowledge relevant to that specific region or sector.

Engaging the Potential Users of Assessment Products. A hallmark of the National Assessment was a concerted effort to include a wide range of stakeholders as appropriate for key issues within regions and sectors throughout the entire process. The process was initiated with a series of workshops held across the country to meet with academics, business representatives, resource managers, rangers, farmers, foresters, and fishers to identify stakeholder issues and concerns. Many of these workshops preceded the formal request to conduct the assessment and shaped the later development of the regional assessments. This effort to engage stakeholders was judged as quite successful (Morgan et al. 2005). All of the workshops had sessions open to the public and were widely announced. The review process included a review of the individual chapters by experts in academia and federal agencies, a review of the full document by a selected panel of experts, a public review and comment period, and a final review by a panel of the President's Committee of Advisers on Science and Technology.

Communicating Scientific Knowledge Accurately and Effectively. The NACCI yielded a variety of products designed to maximize communication to different audiences. Sector and regional teams produced reports and peer-

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reviewed publications that included extensive supporting documentation. The synthesis overview was written with the expert advice of a communication consultant and included a range of graphics and language designed to ensure that the report was readable at the level of the interested nonexpert. The synthesis foundation report was provided to include the documentation and basis supporting the conclusions of the overview. The overview was also used as a basis for press releases and a wide variety of briefings. To the extent that the report was distributed, members of the public and participants in the assessment viewed it as an effective communication document.

Guiding Plans for Future Activities. A specific chapter was included in the synthesis overview, followed by a published article outlining the research needed to address the most important unanswered scientific questions and to improve the ability to inform decision makers. Many of the elements proposed were adopted when the GCRP evolved into the Climate Change Science Program, although this occurred at a time of limited new funding. As a result, very few integrated regional investigations continued to be supported following the conclusion of the National Assessment.

Creating Valued Products. The NACCI publications represent the current standard for comprehensive regional and sectoral analyses of the potential impacts of climate change for the United States. A number of countries have modeled national assessments on the U.S. effort (e.g., China and South Africa), and the assessment process led to independent investigations in areas such as the intersection of climate and human health.

However, the value and the impact of the NACCI at the federal level were limited because the release of the report coincided with a transition in national leadership, and was viewed as a product of the prior administration. Whereas the assessment initially had a clear mandate with a target audience that considered the assessment as salient, by the time it was released the audience had changed and it was no longer viewed as salient or legitimate among some key audiences at the federal level.

Key Strengths and Weaknesses of the NACCI. The National Assessment represents a major step in U.S. efforts to assess climate impacts on the United States in a comprehensive manner. The strengths of the National Assessment suggest that this process had many of the characteristics necessary to produce an effective assessment with some impact on decision making. The National Assessment was, however, the subject of considerable criticism and had limited impact on U.S. policy or in funding new directions in research. The lack of time to produce a phased effort and the lack of better-balanced funding (as well as the fact that this was the very first such assessment of its kind) introduced many opportunities for criticism, including concerns about

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the credibility of some report elements. Significantly, there was a lingering perception by some members of the political administration that received the document that the National Assessment was politically motivated, introducing questions about its legitimacy.

Strengths:

- A well-defined mandate stemming from the GCRA and supported by the Office of the President.
- Well-articulated questions and defined regions and sectors, both of which determined its scope.
- Extensive involvement of experts from all regions and sectors.
- Considerable involvement of a broad range of other stakeholders.
- Broad and extensive review.
- A deliberate, well-planned communication strategy.

Weaknesses:

- The assessment effort was late in getting started, which resulted in the near-simultaneous development of climate scenarios, team guidance, actual regional and sector team efforts, and synthesis. A phased or nested approach would have allowed a phased comment and review and improved opportunities to address issues and problems (e.g., the selection of specific climate model scenarios) as they arose. A prompt start of the work and phased approach would have provided a more reasoned path from sector and regional reports to synthesis.
- The assessment did not have robust funding for regional and sectoral analyses. Lack of funding for some teams and delayed funding for others resulted in unevenness in the team reports, exacerbating the difficulty in creating a coherent and consistent high-quality synthesis of all regions and sectors.
- A change in political administration coincided with the release of the report. With this change, the process lost legitimacy among the new decision makers because it was considered a politically motivated product of the prior administration.

ARCTIC CLIMATE IMPACT ASSESSMENT

The ACIA was undertaken under the auspices of the eight-nation Arctic Council in response to growing concern about how global warming and a host of other environmental impacts (e.g., ultraviolet [UV] radiation increases from ozone depletion, air and water contamination, habitat alteration) affect the sustainability of the Arctic environment with its unique array of ecosystem services, wildlife, and indigenous peoples (ACIA 2004, 2005). The ACIA was conceived when it became clear that assessments by

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the IPCC provided only global perspectives and lacked the in-depth analysis at a regional scale such as the Arctic. The ACIA also followed the Global Environmental Assessment project, which had reflected on lessons learned from global change assessments and provided some guidelines in how to conduct more focused, regional assessments (Farrell et al. 2001). In particular, the importance of treating the assessment as a process instead of a report-producing analysis had become clear.

Establishing Clear Rationales and Appropriate Institutional Structures. The goals for the ACIA were set by its sponsors: the eight Arctic-region national governments, the six indigenous Arctic peoples' organizations, and the International Arctic Science Committee (IASC). ACIA's objectives were to:

- Evaluate and synthesize knowledge and past and present indicators of climate variability, climate change, and UV radiation in the region;
- Assess possible impacts of future changes in climate and UV;
- Provide reliable information to both governments and peoples of the Arctic region to support policy-making processes;
- Recommend policy actions and coping strategies; and
- Provide data to the IPCC for use in its future work.

To ensure that the ACIA had a clear mandate and goals, approximately two years were spent before initiation of the assessment to properly frame and vet the goals; this included conducting a scoping meeting with the interested parties. To develop a sense of ownership, the formal proposal to establish ACIA was prepared, vetted through the Arctic Council and the ASC, and finally presented to the foreign ministers of the eight Arctic countries, the presidents of the six indigenous peoples' organizations, and the IASC council. A political declaration to implement ACIA was approved by the eight foreign ministers.

Designing and Scheduling Assessment Activities. The ACIA established a management structure consisting of various steering and implementation committees and local secretariats. The ACIA scientific process was characterized by transparency, inclusiveness, and broad participation and review of products by the various stakeholders, including both governments and the affected indigenous peoples. The process was designed to emphasize the need for scientific integrity and independence, and required acknowledgement of uncertainties in theoretical models. Decision makers provided input at the beginning to frame the questions and scope of the assessment and at the end by reviewing the document. During review, decision makers were able to weigh in on the policy recommendations but not the scientific

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conclusions. Scientists had the final editorial authority with regards to the science but not the policy recommendations.

Involving the Scientific Community and Other Relevant Experts. The assessment process involved more than 300 scientists and other experts from Canada, Denmark, Faroe Islands, Finland, Greenland, Germany, Iceland, Netherlands, Norway, Russia, Sweden, the United Kingdom, and the United States. The results were reviewed by an additional 225 scientists and experts from the eight Arctic countries and other nations.

Engaging the Potential Users of Assessment Products. The organizers believed it was essential to conduct the process as a partnership between the three principal stakeholder communities: the indigenous residents of the region, the governments, and the scientific community. This partnership began with the vetting process of the formal proposal and continued throughout the assessment. This approach contributed to the assessment's legitimacy and salience. It was also fortuitous that, at the time of the assessment's inception, the indigenous communities and the governments of the Arctic regions were already well organized, all participating in an intergovernmental body called the Arctic Council. In addition, the committee considers it likely that the observed climate changes in the Arctic (e.g., loss of permafrost, coastal inundations) contributed to the perceived salience of this assessment to the indigenous people and regional governments.

Communicating Scientific Knowledge Accurately and Effectively. The ACIA included a particularly well-articulated communications strategy to support the policy-making process. The strategy included postreport outreach to a broad range of audiences, from national governments and multilateral bodies to indigenous councils and the media. A relatively large variety of publications and communications activities were utilized for different audiences; attractive and colorful visual displays complemented the scientific texts. Clear, jargon-free language was employed in reports aimed at both policy makers and the broader public. Journalists and science writers were involved in the assessment process at an early stage. Public forums, workshops, and other educational activities were an important feature of the assessment process.

Guiding Plans for Future Activities. The mandate of the ACIA does not call for repeated assessments, but many people in the assessment community see this as a successful example of a regionally focused assessment. The ACIA leadership has been asked to apply and design such an assessment process for other regions. However, as mentioned above, the ACIA benefited from the fact that the regional governments and indigenous people

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were already well organized, allowing for effective engagement of key stakeholders, which might not be the case in other regions.

Creating Valued Products. The full ACIA scientific report was released in the summer of 2005 (ACIA 2005) and it is still early to make a comprehensive judgment on its overall impact. Yet it seems clear from media reports and other indicators, including references in the U.S. Congress, that the assessment attracted significant attention to emerging climate-related problems in the Arctic. As mentioned above, observed changes on the ground (e.g., summer sea ice extent, decrease in permafrost) are likely to contribute to the timeliness of this assessment and its perceived salience.

Key Strengths and Weaknesses of the ACIA. This assessment was completed fairly recently and many of its effects may manifest in the future; however, the following strengths and weaknesses can be identified.

Strengths:

- A clear and strong mandate with support from decision makers.
- A well-planned, coordinated, and executed communication strategy.
- A transparent model for the science-policy interface during design, implementation, and review.
- Achieved prominence, in part because it was conducted at the same time as some major changes in the Arctic environment, attributable to climate change, were occurring and covered by the major media outlets.

Weaknesses:

- Funding was difficult to secure and not uniform across the participating nations; funds were insufficient to support the entire communication plan (e.g., no funds for printing additional copies of the report).
- Economic impacts were inadequately addressed.
- There was no cohesive plan for follow-up activities.

MILLENNIUM ECOSYSTEM ASSESSMENT

The impetus for the MA (2005a,b) came from many sources, and it was supported by a broad private and intergovernmental constituency. A number of UN conventions deal with a variety of natural resource issues: loss of biodiversity, degradation of arid lands and of wetlands, threats to migratory species, and climate change, which affects all of these changes. The MA was designed to serve these conventions with an innovative construct to answer the fundamental question: What are the consequences of environmental

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change on the functioning of ecosystems and their continuing capacity to deliver services that are essential to human well-being?

Establishing Clear Rationales and Appropriate Institutional Structures. The MA took an integrated approach because a process or sectoral assessment approach fails to capture the complex issues related to the disruption of ecosystems and the services they provide to society. An integrated framework of analysis was developed to reveal the benefits and consequences of human use of ecosystems and the trade-offs caused by societal actions. The MA approach called for a multistakeholder design that allowed broad ownership of the process and the findings.

Designing and Scheduling Assessment Activities. The MA was successful in establishing a consultation process; it had the advantage of a well-designed conceptual framework and also a pilot project before designing a full operational template. A framework for the assessment was crafted by a scientific panel, composed of representative experts, totaling 51 persons, before the assessment work began in 2002 (MA 2003). The entire process was governed by a board, which consisted of representatives from UN organizations, governments (through a number of international conventions), NGOs, academia, business, and indigenous peoples. The framework provided an important template to guide the subsequent work and has proven to be an important document and used by many organizations. This framework was subsequently accepted by the large community that engaged in the work.

The design of the operational program for the assessment was done at two large international design meetings in 2001. A scientific panel was appointed between these two meetings. Four working groups were formed to focus on global status and trends, scenarios, policy responses, and smaller-than-global ("subglobal") assessments. The first three groups were comparable to the work division of the IPCC. The subglobal assessment team was an innovation for such a globally centered assessment. The MA identified 33 regions around the world which varied in focus and scale. One of the subglobal assessments, focused on southern Africa, was targeted to present information at three scales: the village, major watersheds, and large landscape units. All of the working groups interacted through the scientific panel.

The assessment was finished on schedule. A scheduling problem common to all large assessments occurred. The working groups (i.e., trends, scenarios, responses) operated in parallel, rather than sequentially. Although a great effort was made to exchange information among working groups, they did not fully benefit from each other's work. Another scheduling problem was that all of the subglobal assessments had not been completed by the

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end of the global assessment. This was due to inadequate funding, because most of the subglobal assessments were supported by local resources. Thus, dissemination of the findings from the subglobal assessments could not be included in the dissemination efforts of the global working groups.

Involving the Scientific Community and Other Relevant Experts. The MA followed the IPCC model of using a large pool of leading experts from around the world to conduct the assessment. Selection of these experts was accomplished through wide consultation, including calls to governments and other sponsors. The goal was to get scientists of the highest credentials and at the same time, achieve a balance between social and natural scientists plus among countries and between genders. In addition to engaging internationally recognized leaders, fellowships were offered to young scientists so they could learn and assist in the assessment process. Guidelines restricted the information to be included mainly to the published literature. However, they made provision for the subglobal assessments to incorporate traditional knowledge as long as it was traceable. The review of the work also followed the IPCC model by including two rounds of outside review, with the responses to reviews in turn being reviewed by an independent group of experts.

Engaging the Potential Users of Assessment Products. Having learned from previous assessments, the MA took great care to engage the user community at both the beginning and end of the process. The board of the MA consisted of representatives from the UN environmental conventions, who were the primary target audience of the assessment, as well as representatives from many international environmental, resource, and health organizations (governmental and nongovernmental), foundations, academia, the business community, and indigenous communities. Members of the board were active in scoping the project as well as in transmitting the findings to their constituencies. At the end, targeted summaries of results were directed at many of the major user communities.

Communicating Scientific Knowledge Accurately and Effectively. A series of technical reports and synthesis documents were released, starting with the Framework of Assessment in 2003 (MA 2003), and the remainder in 2005 (MA 2005a,b). The MA secretariat distributed thousands of free copies of the framework document to target audiences and hundreds of free copies of the technical reports. The MA web site (*http://www.maweb.org/*) has all of these documents as well as slide show presentations and other outreach materials. The results of the MA were announced, with simultaneous press releases and seminars in major cities (London; Washington, D.C.; Tokyo; Beijing; Delhi; Cairo; Nairobi; Rome; Paris; Stockholm; Lisbon;

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Brasilia; and Sao Paulo), resulting in coverage in major newspapers. The briefings were well attended. Each of the five synthesis reports (biodiversity, desertification, business and industry, wetlands, and health), which were targeted to specific audiences, also had separate launch events in which prime target audiences were involved.

Guiding Plans for Future Activities. The MA was not designed to be a continuing activity yet it produced new datasets on trends that will serve as a baseline for measuring change in subsequent similar efforts. It also provided new analytical tools for analyzing environmental change in terms that are of direct interest to society (i.e., ecosystem services), and for doing so in a way that crosses geographic scales. Interest in the findings of the MA has stimulated possible follow-on assessments by various groups (Loreau et al. 2006).

Creating Valued Products. The MA produced a large set of products designed for diverse communities. These communities ranged from decision makers involved in international environmental conventions to those working at the local levels where subglobal assessments were performed. Specific products were also designed for decision makers in the business community and the health community. An entire volume (MA 2005b) is devoted to policy options and decision support, including analyses of the past success of response options and an explicit chapter on "choosing responses." Technical publications served the science community by providing carefully referenced information as well as information on future research needs. An active web site was established that provided all publications and outreach material. Thousands of copies of the various publications were provided free to focal points of the conventions and other crucial parties.

Key Strengths and Weaknesses of the MA. The MA seems to have incorporated lessons learned from previous assessments such as the GBA and IPCC (Kaiser 2000), contributing to the fact that many design issues have been addressed appropriately.

Strengths:

- Stakeholders from business, industry, academia, NGOs, UN agencies, and indigenous groups were part of a governing board.
- Developed and executed using a conceptual model that centered on ecosystem trends that affect human well-being.
- Focused on global trends but also targeted a sample of subglobal regions and localities. In the latter, traditional knowledge was incorporated.
- Leadership of all of the major components of the assessment had equal representation between social and natural scientists.

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- Working groups were interactive.
- IPCC approaches were utilized throughout the assessment, including evaluation of uncertainty, two rounds of review, and use of an independent review board.
- Strong communication strategy with specific products designed for a variety of stakeholders; wide distribution of products as well as web availability.
- Events publicizing program results held simultaneously in a host of major cities around the world.
- The prime audiences were all of the environmentally based UN conventions, which provided a stimulus for greater interaction among them.

Weaknesses:

- There was no direct government involvement beyond interaction with the Conference of the Parties.
- There was no plan for follow-up activities.

THE GERMAN ENQUETE KOMMISSION

The German Parliament (Bundestag) has the opportunity to create parliamentary investigation committees called "Enquete Kommissions" to address specific subjects of societal interest. As a rule, half of the members who serve on these committees are elected members of the Bundestag, while the other half are experts in the field of the study. This model is notably different from other assessment processes, which in the United States normally do not include politicians. The members work jointly to address the questions under deliberation, so that in this institutional arrangement there is no "firewall" between scientists and policy makers. The rationale for composing an Enquete Kommission with both policy makers and scientists is that scientific findings can be integrated much more rapidly and comprehensively into the parliamentary deliberations.

In October 1987, the Bundestag established, for example, an Enquete Kommission to recommend to the executive branch "Preventive Measures to Protect the Earth's Atmosphere." It was to assess the importance and consequences to the country of stratospheric ozone depletion and of climate change in a comprehensive manner. It advised both the Eleventh and Twelfth Deutsche Bundestag from 1988 to 1994. As of November 1988, this particular Enquete Kommission included 11 members of the Parliament (five Christian Democrats, three Social Democrats, one from the Free Democratic Party, and one from the Green Party) and nine members from the academic and scientific world. The secretariat, which was providing technical help, included eight members in addition to a study director.

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Establishing Clear Rationales and Appropriate Institutional Structures. The terms of reference for this particular Enquete Kommission were established following a motion presented to the German Parliament by two political groups and approved by the Parliamentary Assembly, hence providing a clear mandate. The task of the committee was to collect evidence on global change in the Earth's atmosphere, current scientific knowledge of the cause-effect relationships involved in changes taking place, and to propose national and international measures of prevention and control in the interest of protecting both humans and the environment.

Designing and Scheduling Assessment Activities. The Enquete Kommission determines how it conducts its activities. Reports are expected at stated periods and are presented for discussion to the plenary Parliamentary Assembly. Visits of the committee to specialized institutions and participation of committee members in national and international scientific conferences are scheduled. A list of potential experts who will be invited to testify is established. The topics for expert reports and the related schedule for publication are established by the committee.

Involving the Scientific Community and Other Relevant Experts. External experts originating from the academic, scientific, and industrial sectors are invited to testify before the committee. In the case of the Enquete Kommission on "Preventive Measures to Protect the Earth's Atmosphere," industry representatives as well delegates from the public sector were invited to provide input.

Engaging the Potential Users of Assessment Products. The primary user of this assessment was involved in the deliberations throughout the process.

Communicating Scientific Knowledge Accurately and Effectively. Each month, the Enquete Kommission organized a press conference to highlight the latest findings of the committee and to communicate the content of the presentations made by external experts. Topics discussed by the committee were often featured in the German press.

Guiding Plans for Future Activities. The reports of the Enquete Kommission provide specific recommendations regarding future observation campaigns, laboratory experiments, and model development.

Creating Valued Products. The Kommission produced a series of comprehensive documents that assessed the scientific knowledge on stratospheric ozone depletion and the protection of the tropical forest, and climate

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change. These reports were prepared by the secretariat on the basis of debates that took place in committee. For certain specific topics, dissenting reports prepared by a fraction of the committee may be included.

In addition to chapters that described the state of the science, the Kommission report included sections that recommended specific actions and strategies to address the problems. For example, a 1987 report provided a list of possible actions to protect the ozone layer at the national and international levels (Enquete Kommission 1988). The report called for a drastic reduction in the production and consumption of ozone-depleting substances. The 1991 report (Enquete Kommission 1991) focused on climate change and provided several recommendations for new energy policy. It proposed a 30 percent reduction in carbon dioxide emissions by the year 2005 and called for specific decisions by government bodies, industry, and the public to reach this recommended target.

Key Strengths and Weaknesses of the Enquete Kommission. This assessment provides a strikingly different model for how to provide policy-relevant information to the target audience by directly involving them in the assessment process.

Strengths:

- Strong engagement of political decision makers because the Parliamentary Committee was composed of equal numbers of representatives of the different political parties and the scientific community.
- Direct education of elected members of the Parliament who were members of the Committee.
- Extensive involvement of experts from all regions and different disciplines.
- Considerable involvement of a broad range of stakeholders.
- Deliberate, well-planned communication strategy, carried out through periodic press conferences.

Weaknesses:

- Difficulties in conducting scientific discussions within a Kommission that included some elected parliamentarians with little expertise on the subject.
- Agreeing on specific resolutions was difficult due to political disagreements between members of different political parties.
- Experts selected by the factions of Parliament were not nominated by scientific bodies but directly appointed by a political party, which could have some significant ramifications in terms of the credibility and legitimacy of the process.

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SYNTHESIS AND ASSESSMENT PRODUCTS OF THE U.S. CLIMATE CHANGE SCIENCE PROGRAM

The CCSP oversees and coordinates research on climate and associated global change at 13 federal agencies and is responsible for responding to the GCRA of 1990. The GCRA mandates periodic assessment of global change impacts on the United States (see Appendix B). Therefore, the CCSP proposed in its 2003 strategic plan to conduct the assessment by producing 21 synthesis and assessment reports, each addressing a specific part of the five main goals identified by the program (CCSP 2003; see also Box 1.2). Three objectives of assessments were identified in the strategic plan: (1) to help shape the research agenda in climate change science, (2) to inform efforts for adaptation to climate change, and (3) to support decision making and policy formulation.

Eleven of the reports are intended to address specific unresolved issues related to the understanding and simulation of the climate system. Four reports focus on impacts of climate change on ecosystems and three address direct human impacts (i.e., health, energy, transportation). Three reports deal with decision support (see Appendix C). These reports tend to be narrowly focused on specific issues and thus can be characterized as process and impact assessments. At the time of this writing there is no plan to integrate across the 21 synthesis and assessment products or to produce an integrated assessment of impacts similar to that of the U.S. National Assessment in terms of scope or sectoral and geographic focus.

To date, only the first report, on temperature trends in the lower atmosphere, has been completed (CCSP 2006). A number of others are in review, are available in draft form, and should be officially released in the coming months. The remaining reports are scheduled for release in late 2007 and 2008. Because only one of the products has been completed, the committee has included a description of the approach and some of its strengths and weaknesses, but considers it premature to evaluate its effectiveness. Nevertheless, some valuable lessons can be learned from this approach.

The CCSP developed guidelines for the production of its assessment and synthesis reports (Appendix D). The guidelines call for using an "open and transparent process for soliciting user input, author nomination and selection, expert peer review and public comment, as well as publication and release" (CCSP 2004). Oversight for report preparation, release, and publication rests with the CCSP Interagency Committee.

The initial stage in the process involves the development and approval of a prospectus. The lead agency is responsible for drafting and finalizing the prospectus, which must be approved by the CCSP Interagency Committee. Experts and stakeholders are provided an opportunity to comment on the prospectus in an open process involving an announcement in the *Federal Register* and posting of the prospectus on the web.

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Preparation of the actual report is carried out by lead and contributing authors selected for their technical expertise appropriate to the assessment topic. The lead authors have ultimate responsibility for the drafts. Although users and stakeholders are not specifically included in the report-writing process, the lead authors have the option of soliciting input from users and stakeholders; this solicitation is required to be open and consistent with the report prospectus.

The review of the report is an iterative process initially involving comments from experts and stakeholders in an open process that includes posting of drafts on the web. The guidelines state that "the scientific judgment of the lead authors will determine responses to the comments."

Once the authors have responded to the review comments, the report is submitted to the CCSP Interagency Committee for approval, production, and ultimate release. Publication and release of the report by the Interagency Committee cannot occur until it is reviewed and cleared by the National Science and Technology Committee (NSTC). Approval of the NSTC in turn requires the written release of all members of the Committee on Environment and Natural Resources (CENR). The CENR is comprised of officials from the Executive Office of the President and the 15 federal agencies that have significant programs focused on the environment and natural resources. After approval by the NSTC, the report is published and disseminated using both printing and posting on the web. In addition to the report itself, the comments received during the review process are also posted.

Establishing Clear Rationales and Appropriate Institutional Structures. The CCSP was intended to address the goals of both President George W. Bush's 2001 Climate Change Research Initiative (CCRI) and the GCRA of 1990. This has created an inherent conflict because the goals of the initiative and the 1990 act differ. The CCRI tends to be more narrowly focused on near-term decisions and resolving specific scientific issues than the GCRA. CCSP assessments essentially deconstruct climate issues into many separate, narrow questions that are addressed in individual assessments without integration. Consequently, the structure and approach are not strong in integrating research across sectors and regions or in interdisciplinary science. For this reason the assessment process adopted by the CCSP has been criticized by the NRC (2004) and the Government Accountability Office (GAO 2005) for not including the kinds of integrated analysis intended by the GCRA. One way of addressing this concern without producing a full-blown integrated assessment would be for the CCSP to produce periodic overview reports that summarize the findings of individual reports, place them in a larger context, and discuss policy implications.

A complex hierarchical institutional structure has been imposed on the CCSP assessment process with approval of the report requiring sign-off by

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multiple agencies and departments as well as the Executive Office of the President. There are two concerns with this structure: (1) the complexity of the approval process may delay release of the reports; (2) the requirement that all reports be approved by all members of the CENR appears to give veto power over the report to diverse components of the executive branch. This raises the possibility that nonexpert government officials could attempt to influence the technical content of the report, which has the potential to reduce the perception of legitimacy and credibility. This concern is ameliorated to some extent by the fact that the initial draft reports and reviewers' comments are publicly available on the web.

Designing and Scheduling Assessment Activities. The design of the assessment activity is outlined in guidelines for the scoping, preparation, review, and dissemination of the reports. This design incorporates many of the elements that this committee recommends for assessment reports, including appropriate scoping, transparency, both expert and other stakeholder participation, and an open review process.

The strategic plan calls for the completion of the reports over a three-year period. Due to administrative difficulties, related particularly to FACA requirements, some of the products are behind the schedule for completion outlined in the CCSP Strategic Plan (CCSP 2003). More generally, the scheduling of the assessment reports has been criticized by the GAO (2005) for not meeting the requirements of the GCRA for the completion of a scientific assessment every four years.

Involving the Scientific Community and Other Relevant Experts. The guidelines call for appropriate participation of the expert community in the writing and review of the report. Of particular note is the explicit control given the expert authors over the technical content of the report in the drafting phase.

Engaging Potential Users of Assessment Products. The assessment products planned for the CCSP are process and impact assessments, and the actual preparation of the report is essentially led by the expert community with input from government officials. The level of stakeholder engagement is left to the discretion of each assessment leader. Nevertheless the user and other stakeholder communities have the opportunity to comment and provide input on the report prospectus as well as the report itself.

Communicating Scientific Knowledge Accurately and Effectively. The guidelines on the preparation of assessment reports do not specify communication approaches, and most importantly do not seem to provide guidance on how to characterize uncertainty and confidence limits. However,

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the strategic plan sets forth as one of its five principles that uncertainties require explicit treatment. One of the assessment products focuses on this topic. Thus, it would appear that the specifics with regard to these decisions are left to the authors of each report. It remains to be seen how this critical issue will be addressed in each report.

Guiding Plans for Future Activities. These issues are addressed largely in the overall CCSP mandate and strategic plan. How the individual reports will feed into this process remains to be seen. It is relevant to note that the National Research Council (NRC 2004) found that "CCSP should develop a more comprehensive strategy for implementing and sustaining a global climate observing system." This recommendation was based on its perspective that not only climate observations, but also societal and ecosystem impacts, needed to be monitored more carefully. The lack of integrated assessments in the CCSP plan appears to be consistent with the NRC's critique.

Creating Valued Products. Only one of the 21 products has been released, so it is not possible to comprehensively assess the degree to which the products will be valued by their target audiences. The first product (*Temperature Trends in the Lower Atmosphere*, CCSP 2006) addressed a crucial, contentious, long-standing discrepancy in the scientific community between global temperature trends of the past few decades reported by surface thermometer record and those produced by analyses of the Microwave Sounding Unit satellite instrument. This assessment, by supporting detailed critical examination of methods used to produce alternative trends, reduced remaining discrepancies—both among alternative reductions of the satellite record and between them and the surface record—within the errors of the measurements.

Because the assessment reports themselves tend to focus narrowly on specific questions and short-term goals, it is likely that the products will be of use to specific segments of the stakeholder community rather than the entire community. For example, the first product has been of high relevance to those most interested in understanding the physical characteristics of the current warming and its attribution, but of little relevance to those concerned with impacts and adaptation.

Key Strengths and Weaknesses of CCSP's Assessment Products. The CCSP assessment process is still in its formative phase, making it premature to comment extensively on its strengths and weaknesses. At the time of this writing only one of the 21 planned assessments has been completed and released. This first report appears to have been effective in meeting its objectives, having authoritatively resolved a key policy-relevant scientific question. The report's conclusions have been disseminated widely and

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well received by the relevant user, stakeholder, and expert communities. Although the individual products have the potential to result in effective assessments and achieve their individual goals, the overall approach differs from the schedule called for in GCRA (which calls for an assessment every four years) and it is not clear that the collection of assessment products will provide an integrated view of climate change impacts and possible response options.

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5

Advice for Effective Assessments

Certain strengths and weaknesses, common to several assessments analyzed by the committee, illuminate critical features of effective assessments. For example, a well-defined mandate and consistent support from those requesting the assessment contributed importantly to the effectiveness of the Arctic Climate Impact Assessment (ACIA) and the Stratospheric Ozone Assessments, while the process outcome of the Global Biodiversity Assessment (GBA) was impaired by lack of a clear mandate from the target audience. Several assessments benefited significantly from well-articulated, multifaceted, and extensive communication strategies. The Ozone Assessments were especially effective in providing relevant information for decision-making processes, whereas the ACIA was particularly outstanding in the scope of its communications outreach. Other components of effective assessments included superior leadership, extensive and well-designed stakeholder engagement, and a transparent and effective science-policy interface. Perhaps the most common weakness of past assessments has been a discrepancy between the scope of the mandate and the funding provided for the assessment effort.

Drawing both on the analysis in this and the preceding chapter and on the relevant literature, the committee identified 11 essential elements of effective assessments:

1. A clear strategic framing of the assessment process, including a well-articulated mandate, realistic goals consistent with the needs of decision makers, and a detailed implementation plan.

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2. Adequate funding that is both commensurate with the mandate and effectively managed to ensure an efficient assessment process.
3. A balance between the benefits of a particular assessment and the opportunity costs (e.g., commitments of time and effort) to the scientific community.
4. A timeline consistent with assessment objectives, the state of the underlying knowledge base, the resources available, and the needs of decision makers.
5. Engagement and commitment of interested and affected parties, with a transparent science-policy interface and effective communication throughout the process.
6. Strong leadership and an organizational structure in which responsibilities are well articulated.
7. Careful design of interdisciplinary efforts to ensure integration, with specific reference to the assessment's purpose, users needs, and available resources.
8. Realistic and credible treatment of uncertainties.
9. An independent review process monitored by a balanced panel of review editors.
10. Maximizing the benefits of the assessment by developing tools to support use of assessment results in decision making at differing geographic scales and decision levels.
11. Use of a nested assessment approach, when appropriate, using analysis of large-scale trends and identification of priority issues as the context for focused, smaller-scale impacts and response assessments at the regional or local level.

The committee concludes that attention to these elements, many of which have been identified in the previous literature, increase the probability that an assessment will be credible, legitimate, and salient, and therefore will effectively inform both decision makers and other target audiences. In the following findings and recommendations, the committee provides general guidance for incorporating these elements into future assessments.

FRAMING THE ASSESSMENT

Establishing a Clear Mandate

Whether domestic or international in scope, an assessment will benefit by an authorizing environment that ensures it has a clear mandate and the resources necessary to respond to the task. As described in the case of the National Assessment of Climate Change Impacts (NACCI), the process was greatly facilitated by the fact that it was mandated by the U.S. Global

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Change Research Act (GCRA) of 1990. This requirement helped develop support for the assessment from representatives of the agencies participating in the U.S. Global Climate Change Research Program (GCRP). Similarly, a clear mandate and a strong authorizing environment were provided when a formal proposal was adopted by the foreign ministers of the eight Arctic countries to establish the ACIA. In this case, the mandate by the foreign ministers of the Arctic countries guaranteed that the assessment had a target audience that was not only receptive but also interested in the outcome (Corell 2006). Lack of a mandate can be considered the most significant pitfall of the GBA (Watson 2006). Although the GBA was established by the United Nations Environment Programme to provide a scientific basis for the Convention on Biological Diversity (CBD), it was never formally authorized by the CBD and as a result encountered a number of barriers that might have otherwise been avoided.

These examples illustrate how an assessment with a clear mandate from decision makers is more likely to be viewed as legitimate and salient, particularly if the mandate specifies the degree to which the assessment should identify and evaluate policy or other response options. In fact, maintaining legitimacy requires an assessment to respect the boundary between science and policy, which means that it is to provide policy-relevant information and not to exceed its mandate by providing policy-prescriptive recommendations unless clearly asked to do so.

Specifying Goals and Objectives

The state of the relevant scientific knowledge and the decision-making context that an assessment seeks to inform affects the kinds of decisions to which it is relevant, which in turn should help define the appropriate goals and objectives of an assessment. For example, the goal may be to establish the state of knowledge, to indicate the latest understanding of impacts, or to provide response options. For the last, the goal might be to provide information on the effects of alternative response strategies on relevant impact categories. Different goals will have profound implications for the decisions undertaken during the course of an assessment. Confusion on the part of participants regarding the goals of the assessment can severely limit its effectiveness. Assessment participants must come to a mutual understanding of what they are being asked to do in response to the charge.

As part of the mandate, goals and objectives need to be well articulated, including the kinds of decisions that the assessment should inform, how the assessment will be implemented, and how progress toward goals will be measured (NRC 2005). In particular, in the scoping phase of the assessment, organizers need to identify the target audience and the decisions it is intended to inform as well as the types of information needed to make

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those decisions. The ACIA provides an excellent example of an assessment with clear goals and objectives that were set by the sponsors. These goals appeared to remain intact throughout the assessment process.

Since external conditions may evolve, goals and objectives may have to be adjusted during an assessment to remain salient to the target audience. The ozone assessments provide an exemplary case of an adaptive assessment process, including explicit changes in goals and objectives made by the authorizing body in response to changes in the state of the knowledge. When changes in approach are required, they should involve a deliberate and transparent decision on the part of the authorizers and leadership of the assessment to ensure legitimacy. To ensure credibility and legitimacy, the rationale for such changes has to be well documented.

An Appropriate Framework

Because design choices made during the initiation of the assessment tend to be structural and difficult to change once the process is under way, they have to be considered carefully. An appropriate framework, which may vary depending on the type of assessment, is required to answer the mandate effectively. Ideally, the framework is specified in advance to guide the process. Problems often arise when a discrepancy exists between the questions to be addressed and the framework and approach used.

The ACIA took great care in preparing such a framework by conducting meetings during a two-year planning phase prior to initiating the assessment process. It drafted a proposal specifying the approach, which was vetted by the Arctic council and the participants. It provided clear guidelines and guaranteed ownership by the relevant target audience and stakeholders.

The ozone assessments and the Intergovernmental Panel on Climate Change (IPCC) provide good examples of choosing an appropriate framework. Both of these studies include effective response assessments in addition to process and impact assessments. The focus on identifying specific technologies to reduce environmental impacts in particular applications or industrial processes seems to have benefited especially the ozone assessments, given the impact the Technology and Economic Assessment Panel (TEAP) had on technology choices, and hence decision making, in the private sector. The attempt to engage individuals from the private sector with the necessary technical expertise to distinguish technical feasibility from economic feasibility has been particularly noteworthy. Therefore, the committee considers the TEAP a particularly effective model for a technology assessment, a special case of response assessment.

Although the NACCI was designed primarily to be an impact assessment, it required the development of scenarios linking atmospheric concentrations of greenhouse gases to their impact on key climate variables.

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Outputs from general circulation models were developed based on scenarios of human and natural emissions to provide the inputs for sectoral and regional analyses. In fact, most assessments of the impacts of global change nevertheless require incorporation of basic science (process assessments). Since the NACCI was not limited to incorporating references to preexisting literature in assessing impacts, it was able to use the latest model run outputs. However, because of a late start, it was not able to incorporate a phased approach in the selection of specific climate model scenarios. As a result, those responsible for the impact assessment were lacking some of the necessary scientific information to guide their deliberations. In addition to timing issues, the NACCI was also criticized because the models were not generated by U.S. scientists. This example illustrates how the choice of information to be included may affect the credibility of the process, but more importantly, it stresses the importance of project management and timeliness.

The NACCI also illustrates how important the choice of scope and geographic scale is for many other design issues of the assessment. The scope and scale of the assessment should be chosen to match the scope and scale of the decisions it is intended to inform. In the case of climate change, there are a multitude of decisions at various scales spanning numerous public- and private-sector decision makers that could potentially benefit from an assessment. The scope and scale of the information produced (among other considerations) will determine whether or not the assessment outcomes are salient. The choice might also require a phased approach—for example, starting with a more global or national assessment, followed by regional-scale assessments. In fact, the NACCI process was intended as an iterative process, where the national assessment would inform the regional-scale assessment and vice versa. Clearly, such decisions have to be addressed during the inception of the assessment as part of the general framework.

The framework is best specified in a guidance document. This guidance document needs to clearly articulate the mandate and specify the decision the assessment should inform, which will guide the type of assessment (process, impact, response) required. Other issues that the framework should specify include the degree of integration necessary, scope, timing, target audience, leadership, communication strategy, funding, and measures of success. In addition, the respective roles of those requesting and those funding the assessment in scoping the assessment should be clarified in the original guidance document in order to avoid major discrepancies between the assessment's mandate, expected results, and available funding. Establishing these guidelines in advance and putting them through a vetting process will greatly enhance salience, credibility, and legitimacy.

It is also important to specify how information is judged as credible enough to be included in the assessment. Standards must be established

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for the inclusion of information. In the case of process assessments, this may simply require a decision on whether only peer-reviewed information should be included or whether original research, not yet peer-reviewed, can be considered. In the case of impact assessments, the development of standards become much more difficult, because of the need to include stakeholder information, such as indigenous knowledge, and the need to make some degree of value judgments. Further, integrated assessments will result in new combinations of multiple types of preexisting knowledge. Although alternative interpretations of the knowledge base are inevitable and must be reflected in the report, standards must be developed to determine what belongs in the knowledge base and how to reflect uncertainty. To ensure the greatest credibility, the knowledge base must be evidence based and not value based, particularly in impact assessments.

Recommendation: The leadership of and those requesting assessments should develop a guidance document that provides a clear strategic framework, including a well-articulated mandate and a detailed implementation plan realistically linked to budgetary requirements. The guidance document should specify the decisions the assessment intends to inform; the assessment's scope, timing, priorities, target audiences, leadership, communication strategy, funding, and the degree of interdisciplinary integration needed; and measures of success.

Strategic Plan for CCSP's Assessment Activities

Although the U.S. Climate Change Science Program (CCSP) has a mandate under GCRA to conduct assessments, the program lacks a long-term strategic framework for meeting this mandate. Prior to undertaking future assessments, CCSP will need to clearly express long-term goals for the program as well as specific goals for each assessment, specifying decisions the program intends to inform. A strategic plan comprising overall goals, mandate, and implementation strategy for CCSP assessment activities would enhance the salience, credibility, and legitimacy of future assessments—especially if the plan is accepted at high levels of government as well as within the science agencies and the scientific community. Such an overarching long-term strategic plan for CCSP assessment activities would foster programmatic and funding continuity that could adapt to evolving circumstances and to changes in political administration.

Recommendation: The CCSP should develop a broad strategic plan for its assessment activities that focuses not only on a specific short-term objective, such as preparing the next report or assessment product, but also on longer-term objectives that are in the national interest.

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ADEQUATE FUNDING

A common problem of several past assessments has been the discrepancy between the mandate and the funding. For example, the NACCI was funded within preexisting agency budgets, and funds were not available for all regions and sectors in a timely way. This resulted in limited support for some teams and delayed funding for others. Overall, it led to unevenness in the team reports and exacerbated difficulties in creating a coherent and consistently high-quality synthesis of all regions and sectors. The budget for the GBA was much lower than for other global assessments of its scope. This had a deleterious effect on the number of meetings that could be held, the number of reports that could be prepared and published, and the size of the support staff. Because funding is required for a broad and representative participation of experts and stakeholders; for administrative support to facilitate the compilation, writing, and review of the product; and for an extensive communication, dissemination, and outreach efforts, insufficient funds can jeopardize critical aspects of an assessment. This discrepancy between mandate and funding can stem from the fact that those who mandate the study do not actually fund it. As an example, ACIA had a very clear mandate from the Arctic Council and the International Arctic Science Committee; however, the funding came from government agencies in the eight Arctic nations. This became a problem from the beginning because the agencies tasked with providing funds were not all fully supportive of the activity.

When broad expert participation is required, the legitimacy of the assessment might be questioned if insufficient funds are available to support individuals from stakeholder communities who would not otherwise be able to participate. Lack of sufficient funding can have a particularly negative effect on the legitimacy of a global assessment if it limits or prevents developing-country involvement.

A well-designed communication strategy requires significant administrative support throughout the process, particularly at the end for dissemination. Therefore, funds need to be reserved for the final phase when intensive outreach and dissemination efforts are required. Because inadequately funded assessments may have to shortchange critically important process steps that lead to the loss of credibility, legitimacy, and/or salience, organizers must be especially strategic about proceeding with the assessment if funding sources are not secured from the outset. Therefore, organizers need to address the following questions before initiating the process: Does it make sense to begin with insufficient funding in the hope that additional resources will become available? If so, what are the implications from a process perspective relative to the goals and objectives? Will it compromise the credibility of the assessment? Should the mandate and scope be adjusted to the available funds?

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Although the presence of a clear mandate can provide the impetus for fund raising, few assessments had as clear a mandate at their inception as the NACCI, yet a funding shortfall turned out to be a significant problem. An additional consideration relative to funding is the need for programmatic continuity, especially in light of the potential for major changes in direction that result from changes in administration. Since global change research necessarily requires a long-term perspective, abrupt changes in focus and scope can lead to losses in salience, credibility, and legitimacy.

When preparing a framework to be vetted and approved by the sponsors and participants, it is desirable to have the framework contain sufficient detail to link key activities to resource requirements. Large budget items should be anticipated and agreed upon by the key players, with realistic estimates of costs. Failure to anticipate the full range of funding needs can lead to underfunding and an uncertain outcome. It is difficult to raise funds during an ongoing assessment.

Recommendation: Resources made available to conduct an assessment should be commensurate with the mandate. Therefore, the guidance document for the assessment should clarify the role in scoping the assessment mandate of those who are requesting and funding it. The budgeting of resources should focus on ensuring the success of the highest-priority components of the assessment, including aspects that have been shortchanged in the past, such as supporting broad stakeholder participation, communication activities, and dissemination.

ASSESSMENT BENEFITS, OPPORTUNITY COSTS, AND EFFICIENCY CONSIDERATIONS

Assessments as well as the activities tailored to support assessments have mobilized a large number of scientists over the last decades. This effort has affected the national and international research agenda and has engaged research institutions and universities in new types of activities. In certain cases, the need to participate in assessments has facilitated the development of new research disciplines or has brought together different scientific communities that had never cooperated in the past.

The Climatic Impact Assessment Program (CIAP) organized in the early 1970s by the U.S. Department of Transportation provides a striking example that illustrates how the need to address a specific and urgent environmental question has contributed to the development of a new research field. CIAP brought together specialists in dynamic meteorology, radiative transfer, and atmospheric chemistry and led to the formation of a new research community that specializes in questions of the middle atmosphere. This community played a decisive role a few years later when the ques-

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tion of ozone depletion by industrially manufactured chlorofluorocarbons became an important issue. In many other cases, assessments have brought together experts from different disciplines, teaching them to work together and resulting in subsequent interdisciplinary research projects. In addition, assessments can articulate the progress, limitations, and opportunities associated with climate research and promote new directions of research by better defining critical scientific questions and research needs.

Although striving for credibility, legitimacy, and salience is likely to result in an effective assessment, the process might pose a daunting workload and might seem burdensome and inefficient. This issue is exacerbated by the growing number of assessments in which U.S. scientists are involved and the fact that many ongoing assessments are growing in magnitude (Mitchell et al. 2006). The number of experts who participate and the volume of the output are sometimes used as implicit indicators of the credibility and seriousness of the assessment activity (Reid 2006). However, if these indicators are taken to their limit, the assessment process may have diminishing returns and may no longer be efficient. It is important to balance the human and financial costs associated with any assessment against the value and impact of the assessment outcome. More importantly, one has to consider the opportunity cost associated with the human resources being devoted to assessments instead of advancing the scientific understanding of the issue itself.

The assessments examined by the committee have provided significant and tangible benefit, but they also provide valuable perspective on the human resources invested by the scientific community that is not focused on research. To illustrate the growing demand on human resources by assessments, consider, for example, the following observations about U.S. assessment activities:

1. The number of global change assessment activities is increasing, including some 21 activities planned or under way by the CCSP, which are combined with U.S. leadership or participation in many other activities such as the IPCC.
2. The scale of assessments is growing significantly. The IPCC is a good case in point. Consider just the metric of the size of the reports. In 1990, 1995, and 2005, the scientific assessment portions of the IPCC were 364, 570, and 881 pages, respectively. The impacts and vulnerabilities sections in 1990, 1995, and 2000 were 242, 447, and 1032 pages, respectively. The response strategies topics in 1990, 1995, and 2000 were 270, 447, and 750 pages, respectively. An argument could be made that these increases in volume describe the wealth of investment and accomplishment associated with new research, but it is also evident that the reports increasingly tend to be comprehensive documents rather than statements of progress or

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identification of issues. In 2000, the synthesis report for the IPCC alone was 396 pages long. This increase in volume often does not stem from an increase in mandate but from the difficulty assessment participants have limiting the scope and the amount of information to include. The IPCC is not the only assessment generating considerable volumes of information. For example, the first Millennium Ecosystem Assessment (MA) produced 81 chapters totaling more than 3,000 pages.

3. Many major assessments include a schedule for repeating the process at regular intervals. For example, the act of Congress that created the GCRP also requires national assessments on four-year intervals; the first comprehensive national assessment on climate change was completed over a four-year span, and the current U.S. national assessment effort is now producing 21 synthesis and assessment reports by the CCSP. The IPCC is scheduled at five- to six-year intervals. However, the next IPCC assessment starts immediately upon completion of the last, and it has become essentially a continuous process. There is a perception that the rate of scientific progress is slower than the rate at which the assessments are being conducted. The Ozone Assessments under the Montreal Protocol requires assessments of science, impacts, technology, and economics every four years but is notably an exception, in that it was designed to include updates on the science only and appears to be producing shorter reports with time.

4. Assessments involve hundreds of climate and climate-related scientists. The tasks of lead authors for the IPCC chapters of various working groups require a significant time commitment. Similarly, the MA involved 1,360 experts from 95 countries. The investment in time includes not just the number of authors, but also the number of reviewers. Consider, for example, that the MA processed 20,745 review comments from 2,516 experts.

5. There are more than 200 international treaties, most of which require periodic assessments (Mitchell et al. 2006). In 2003 alone, more than 12 such assessments were under way, each engaging hundreds to thousands of scientists.

The considerable time investment also raises questions about the potential for the following unintended and undesirable consequences:

1. The level of review and the willingness of reviewers to evaluate assessment products may decline with volume and repetition. As a case in point, in the NACCI, the 5-page description of the climate basis included in the overview chapter received 18 pages of expert review (federal agencies and solicitations from expert scientists), while the 60-page foundation chapter, which served as its basis, received only 3 pages of expert review. During the public comment period, the overview received 10 times the vol-

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ume of comments as the foundation section on climate. Two conclusions are possible from this analysis. First, the community perceives that the synthesis or overview report element will have more impact and therefore is more important to analyze and comment upon. Second, reviewers are taxed by the volume and, therefore, few are willing to review an entire assessment report. Unfortunately, the level and/or quality of review may decline if the task is too onerous.

2. The growing magnitude of the assessment process may begin to change the participation by scientists from different communities. The magnitude of the effort can influence whether the best expertise can be engaged in the process, either because the "best" experts are often already quite busy or because they may have experienced some burnout in earlier activities and not be willing to serve on additional assessments. Participation may be particularly challenging for young university scientists because of the combined teaching and research mission of these individuals. Since participation in comprehensive assessments cannot be budgeted as sponsored research or teaching, it becomes an unfunded mandate for university researchers. Consequently, the job descriptions (nongovernmental organization [NGO], university, government) and career level of the scientists who participate may change with the growing magnitude and repetition of assessments.

3. The motivation for participation in any assessment process changes if the process becomes too time consuming. If the assessment is perceived to be of considerable political importance or contentious, then the process may motivate participation from the tails of distribution of scientific opinion or perspective to either help ensure or help prevent a particular outcome.

4. The impact of assessment products will also change with the volume of reports simply because stakeholder comprehension and willingness to read lengthy reports will decline. The most important outcomes of an assessment may also be blurred by the sheer volume of the discussion.

One conclusion from this analysis is that the human and financial resources required to create a credible assessment should be examined at the start of the process and actions incorporated to ensure that the use of the resources is effective and efficient. Given the important contribution of assessments to policy making and to society in general and growing number of international treaties and national mandates, considerations of efficiency become increasingly important to minimize the opportunity cost to the research community. It may also be time to consider alternative modes of participation, changes to the assessment process, or both, particularly for assessments that are scheduled to reoccur at a given interval. Possibilities include the following:

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1. Define specific requirements to add more focus to ongoing assessments so that they are limited to addressing significant new advances (e.g., IPCC) as opposed to being comprehensive. In this manner, the opportunity costs for researchers can be limited. Such an objective might be enabled, for example, by enforcing page limits. This would change the scientific discussion by forcing participants to debate and consider only the most significant results and limitations, rather than trying to be comprehensive in literature searches, citations, and discussions. The short text would promote a higher-quality review by a broader spectrum of scientists. The impact of the report could be greater, especially if it focuses clearly on the most critical aspects of the research outcomes. In addition, the focus on brevity and impact would better enable the best and most involved scientists to participate and perhaps permit greater scientific participation in a larger number of assessments.
2. Consider having fellowships for young scientists (as done by the MA) or specific opportunities for funding participation by U.S. scientists. The funding could be provided based on peer review, with the objective of identifying and supporting those best able to produce a credible and representative report.
3. For major assessment activities, consider nested approaches that phase the contributions of different elements of the community. For example, the process assessment could be undertaken first, followed by an impact assessment, a response assessment, or both. Similarly, process assessments could be undertaken at the global or national scale first and used to provide information for process assessments and impact assessment at a smaller, more regional or local scale. In this manner, U.S. assessments could focus on more regional scales if international efforts are acknowledged and used to build national assessments, rather than conducting a redundant effort.
4. Budget adequate time in the implementation plan for products to be developed. For assessments that are conducted at regular intervals, evaluate the appropriate interval every so often by considering the rate at which new scientific information becomes available and the rate at which the policy context changes and thus requires new questions to be assessed. Depending on the balance between the rates of evolution of the available science versus the decision-making context, consider producing focused, fast-tracked assessments, with an emphasis on the latest improvement in the understanding of an issue required for the evolving policy context.

Acknowledging previous assessment efforts as a starting point is particularly relevant to climate change assessments such as the IPCC and U.S. climate change assessments because U.S.-funded research and scientists already play a major role in supporting the IPCC efforts. Therefore, it seems appropriate that such efforts form the basis of U.S. assessments.

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Recommendation: Care is required to make sure that the burden on the scientific community is proportional to the aggregate public benefits provided by an assessment. Alternative modes of participation or changes to the assessment process—such as limiting material included in regularly scheduled assessments or running "nested" or phased multiscale assessments—should be considered. As appropriate, U.S. assessments should acknowledge the work of the international community and avoid redundant efforts.

TIMING AND FREQUENCY

A frequent criticism of assessments is that the information is not delivered at the timescale required for the decision-making process. It is critical that a realistic time line be laid out at the design stage with regard to the products of the assessment. Once the schedule is set, expectations need to be managed and met if the credibility of the process is to be maintained. This requires a delicate balancing of the needs of the decision-making community with the knowledge and resources available.

For example, a major criticism of the NACCI was that the assessment effort was late in responding to its congressional mandate. This resulted in the near-simultaneous development of climate scenarios, team guidance, regional and sector team efforts, and synthesis. Perhaps even more problematic was the fact that a change in administration coincided with the release of the report. With this change, the original salience of the report was lost and major legitimacy issues were raised.

The German Enquete Kommission produces assessments that tend to meet the time requirements of decision making by including policy makers and scientists in the ongoing process. Therefore, policy makers benefit from the latest information at the time it becomes available. Indeed the stated rationale for composing investigation committees with both policy makers and scientists or practitioners is that scientific findings can be integrated much more rapidly and comprehensively into parliamentary deliberations. At risk, however, is credibility because scientific discussion within the committee involves individuals from different political parties who may or may not have a scientific background. This can make reaching agreement problematic and may require political compromise.

Assessments such as the IPCC are conducted periodically, thereby offering an opportunity to provide a summary of the state of knowledge at regular intervals. Although this ensures a steady updating of information as mentioned above, it tends to be resource intensive and has led some to question whether such assessments should take place at fixed intervals or instead be driven by the rate of change in the underlying knowledge base. Because of the efficiency issues described in the previous section, the rate at

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which new information becomes available has to be balanced carefully with the urgency of the decision-making process when deciding on the frequency and scope of assessments.

Consequently, a realistic time line is essential to accomplishing the goals and objectives of an assessment. However, because assessments often have to meet deadlines driven by the mandate or the decision processes they hope to serve, they have sometimes been developed without adequate care given to matching the timeline to a realistic assessment of the amount of work required.

Recommendation: The time line must be consistent with the goals and objectives, the underlying knowledge base, the resources available, and the needs of the decision-making process that the assessment is intended to inform.

IDENTIFYING, ENGAGING, AND RESPONDING TO STAKEHOLDERS

Stakeholders, defined here as interested and affected parties, include several specific categories that are distinguished in this report due to the need to strategically engage diverse groups. The target audience is a subset of stakeholders comprised mainly of those making the decisions the assessment intends to inform, who are sometimes also referred to as the "users" of assessments. It includes intermediaries such as NGOs, professional organizations, and other "science translators" (e.g., a congressional staff person). Those who request and fund the assessment are also a specific subset of the target audience. Another important group of stakeholders are the experts participating, producing, or leading the assessment. Lastly, a large subset of stakeholders consists of those potentially affected by the policies resulting from the use of assessments who may not have been part of the process.

The assessment community has recognized the importance of broad engagement of stakeholders in order to ensure salience and legitimacy. In this section, the committee discusses issues related to addressing the needs of specific target audiences, establishing appropriate boundaries at the science-policy interface, engaging stakeholders beyond the target audience, building the capacity of stakeholders to engage in assessments, and a comprehensive, multifaceted communication strategy. Meeting this objective may require significant resources and may thus need to be balanced with efficiency considerations. However, the importance of stakeholder engagement to the overall success of an assessment implies that budgetary provisions, especially for communication, should reflect this reality.

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Defining and Responding to the Target Audience

Defining and responding to the needs of the target audience is a critical component of an effective assessment process, requiring a continual dialogue between scientists and the target audience. Involvement of the target audience will also promote legitimacy and ownership of the process. As such, the intended audience needs to be identified in advance along with its information needs and the level of specificity required for that information to be useful. Such dialogue often provides surprising insights about the science itself as well as giving focus to research questions. The Enquete Kommission offers such an example, in which the target audience participates fully in the process and is engaged in a constant dialogue. In such a process, the science topics can be modified based on user demand to continuously ensure salience, but the conclusions drawn from the science should not be changed in response to user demands due to the resulting loss in credibility.

Because many assessments have diverse stakeholders, it may not be possible to deliver relevant information to all potential audiences. For the ACIA, the target audience (the Arctic council and the tribal councils) was well defined and organized from the beginning, was heavily involved in its initial framing phase, and was also involved in the review process. A deliberate process needs to be used to identify and engage the most important and appropriate audiences. For example, the consideration of impacts at an aggregate level may be useful for those who are responsible for negotiating climate treaties at the domestic or international level, but it will be of little value to those responsible for managing a water resource basin, improving the resilience of an electric power system, or making local land-use decisions. Information must be tailored to an appropriate decision-making scale to be useful. However, the limitations of downscaling information to the local scale need to be well articulated. The approach of the MA might set a useful example of how decisions at multiple scales can be informed. The MA provides information at the global scale but has nested within it assessments at the regional scale and, hence, targets multiple audiences at the same time.

The target audience for an assessment may also comprise intermediaries, such as media, NGOs, professional organizations, business associations, or other "science translators," such as policy advisers and congressional staff members. In many sectors, these intermediaries are consultants or specialists within an industry who focus on translating the assessment information into products that are designed to support particular kinds of decisions. They are commonly the most sophisticated users of assessment products and are therefore a critical target audience.

Managing expectations is important to the success of an assessment. It is critical that the target audience knows exactly what the assessment is

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intended to be used for and, just as importantly, what it is not intended to be used for. For example, an assessment may focus on regional and sectoral impacts and opportunities for adaptation, but, by choice, exclude issues related to mitigation options and response strategies. Given the resources, stakeholder demands, and political environment, this may be a perfectly rational design. However, it will limit the audience for an assessment. Hence, expectations regarding the context of the assessment must be managed from the outset.

Depending on the type of assessment, audiences may include governments, the private sector, civil society or NGOs, and the scientific community. Responding to the needs of this broad spectrum of target audiences is costly in terms of human and financial resources. Most scientists are not well equipped to design and manage interdisciplinary science-policy discussions; expert facilitators may be required to bridge this knowledge gap successfully. Finding individuals, skilled at handling this interface, can be difficult. Financial support for this activity has been limited in the past, and it has been difficult to maintain the continuous dialogue with the appropriate target audiences.

Providing decision makers with the information they need when they need it is a laudable goal for any assessment. At the same time, given that decision making is very likely to take place at a different pace than the scientific process, assessments are prone to the criticism of not providing information at the level of detail requested by policy makers on the time scale they desire. Salience can be lost by providing information too slowly to meet the needs of an evolving policy process. At the same time, credibility can be lost by providing results that are considered premature by the scientific community. Therefore, the timing of information should play a crucial role in the design of an assessment; however, decision makers need to be realistic with regard to their expectations of when the information will become available and with what degree of certainty.

Because policy making is a dynamic process with many opportunities to learn and make midcourse corrections, a continuous dialogue with the target audience could allow the assessment process to adjust to the changing needs of decision makers, as long as it remains consistent with the overall mandate and true to the scientific evidence.

Recommendation: The intended audience for an assessment should be identified in advance, along with its information needs and the level of specificity required for assessment products to be most salient and useful. In most cases, the target audience should be engaged in formulating questions to be addressed throughout the process, in order to ensure that assessments are responsive to changing information needs. Both human and financial

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resources should be adequate for communicating assessment products to relevant audiences.

Boundaries at the Science-Policy Interface

Defining an appropriate interface between an assessment process and the policy makers who requested and pay for it is a critical challenge in assessment design. While the involvement of decision makers in local, state, or federal government is crucial to ensure the salience of the information provided, boundaries might be required to ensure the credibility and legitimacy of the process. In particular, those providing the funding and authorization for the assessment should not be in a position to influence the scientific conclusions. The ACIA offers an effective model: policy makers and scientists collaborated in the development of the executive summary of the report. In this collaboration, scientists were given the authority and veto power over the scientific content. In contrast, in the IPCC process, the political oversight and negotiations before the release of the Summary for Policy Makers has led scientists to question the credibility and legitimacy of this particular part of the review process. It would be preferable if the process allowed scientists to retain the ultimate editorial authority over scientific conclusions, as long as a neutral and properly managed review process is in place to ensure that review comments are addressed appropriately. Because the NACCI had such a clear and strong mandate from one administration, it became vulnerable to criticism by the subsequent administration that it was a politically motivated process and was lacking legitimacy. It is conceivable that if more explicit and well-defined boundaries had been in place at the science-policy interface from its inception, this perception of illegitimacy could have been minimized.

How and where to establish the boundary between the assessment producers and those who requested the assessment depends in part on the specific political environment in which the assessment is produced. In the case of the Enquete Kommission, boundaries at the science-policy interface are minimal, resulting in an institutionalized collaboration between policy makers and scientists delivering the information to the decision-making process in the most timely and most effective manner. Such a process might not achieve the same level of credibility and legitimacy for an assessment conducted in the United States, because the cultural assumption in the U.S. science community is that credibility stems from a scientific enterprise fully independent of policy issues and that government review of science can result in credibility problems. Independent of where along the spectrum the science-policy interface falls, each community must maintain its self-identity and protect its sources of legitimacy and credibility. Boundaries are

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therefore commonly negotiated, articulated, and maintained by assessment participants (Farrell et al. 2006).

Ideally, neutral facilitators can monitor the boundaries. For example, a team of review monitors, composed such that the team is balanced overall in opinions and biases, with experts both from the policy and the science communities who were not involved in the preparation of the assessment, could referee the policy review of the document. The review monitors would ensure that scientists are responsive to amending the policy options or recommendations and that the government review does not attempt to alter the scientific conclusions.

Recommendation: The leadership of and those requesting the assessment should establish a transparent and deliberate interface between participants and those who request or sponsor the assessment. Clear guidelines and boundaries should ensure both salience to those requesting the assessment and legitimacy, especially with respect to the perceived influence those requesting the assessment might have over the scientific conclusions drawn.

Science-Policy Interface for CCSP Assessments

CCSP's assessment activities have raised credibility and legitimacy issues with some stakeholders, particularly in the science community, because of the way the boundary between science and policy was designed. For example, each assessment product is reviewed by the government and requires approval by high-level government officials, raising the questions of whether the users of the assessments not only control the questions being asked but, at least potentially, also the scientific conclusions. This concern is addressed to some extent because CCSP posts the report in both the pre- and postreview version to allow tracking of the changes. Nonetheless, there remains skepticism about the degree to which government influence may affect scientific outcomes, not only through funding but also through review of final products. Perceptions about the degree of government influence can diminish the value of an assessment in the eyes of many stakeholders. Such perceptions may be difficult to overcome, making it especially important to establish guidelines that will stand the test of time.

Recommendation: CCSP needs to further develop and better communicate a government review process that is considered legitimate and credible by all relevant stakeholders.

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Stakeholder Engagement in the Process: Balancing Credibility and Legitimacy

Despite general understanding that broad stakeholder engagement can contribute importantly to a successful assessment, how to identify appropriate stakeholders and engage them effectively is not self-evident. Participation of broad audiences throughout the assessment process may increase legitimacy and salience, but it could also weaken the credibility of the process. In addition, the involvement of too many stakeholders could make the assessment process inefficient and too costly. The appropriate balance between broad stakeholder engagement to achieve legitimacy and salience, and the need to achieve efficient, and credible outcomes, will depend on the specific context of each assessment; it will require careful consideration early in the assessment design process.

Despite the tension between various interest groups, it is the experience of committee members that, in many kinds of assessments, more benefits and impact come from engaging stakeholders in the process than from communicating the final product. The ACIA process is a successful model for stakeholder engagement, which was characterized by transparency, inclusiveness, and broad participation by the various stakeholders, including both governments and affected indigenous peoples. The ACIA process benefited from the fact that most stakeholders were already organized; hence, trusted representatives from indigenous peoples' organization were able to participate and speak on behalf of their organization. This simplified and improved communication with the relevant stakeholders significantly.

A clear and transparent approach to soliciting and selecting stakeholder participation or input needs to be designed during the framing process and included in the guidance document. Since participants are also stakeholders in the process, each participant will bring to the assessment a bias and potential conflict of interests. Requiring all participants to openly state their biases can help ensure that the composition of the committee includes an overall balance of opinion and biases. The legitimacy of any assessment process would be enhanced by a transparent and deliberate approach to ensuring a balance in the opinions of its participants.

Stakeholder engagement builds trust between individuals and between categories of users; results in broader understanding of multiple perspectives; and builds a shared knowledge base that may be useful in other applications. However, it must be recognized that there is a direct relationship between the number of individuals and organizations that engage in a process, either as stakeholders or as participants, and the degree of difficulty in arriving at a consensus. Larger and more inclusive assessments have a lot of "transaction costs" because of the need to bring all participants to a common level of understanding of the science as well as of the goals and objectives of the assessment. Nevertheless, the NACCI provides an example

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for successful stakeholder engagement (Morgan et al. 2005). The NACCI was characterized by a concerted effort to include a wide range of stakeholders throughout the entire process, as appropriate for key issues within regions and sectors.

A host of critical questions arises regarding who participates in assessments and who the recognized stakeholders are: What disciplines and perspectives should be represented? What sectors, ethnic groups, interest groups, or international entities and governments need to be represented? Who should select the representatives? What criteria are used for the selection? All of these questions have to be addressed carefully and deliberately, ideally in the guidance document, while acknowledging that it is generally better to err on the side of inclusiveness.

Different categories of assessments have inherently different types of stakeholders. In the case of process assessments, stakeholders include the relevant social and natural science experts and agency representatives, particularly when the assessment is expected to inform decisions regarding future research priorities. Although the committee has noted in earlier chapters that the model for producing process assessments is well established, involving hundreds of experts drawn from a variety of disciplines, decisions on how to balance the disciplines are not always as well considered. Because understanding the impacts of global change is extremely complex, it requires the involvement of a multitude of disciplines, and inadvertently excluding any key expert group can lead to a loss in scientific credibility and potentially legitimacy. However, balance is also a critical feature. An additional challenge results from the fact that in most instances, scientists receive no direct financial compensation for their involvement, which may exclude certain experts from participation due to lack of support. Funding issues may limit some categories of potential participants, presenting a challenge to balanced stakeholder participation; the equity implications of funding and need to be considered when planning the stakeholder engagement process.

In the case of impact and response assessments, participation should include the involvement of governments, the private sector, and civil society or NGOs in addition to the scientific community. However, their roles may differ both within and across assessment activities and may depend on which phases of the policy process the assessment intends to inform. Especially if response assessments strive to provide policy options, relevant policy makers must be involved at least in the review process.

In integrated assessments, balancing the participants by disciplines (e.g., natural and social scientists), sectorally, and geographically is an important design consideration. In the international context, more care needs to be given to engaging a broad spectrum of experts, particularly in balancing experts representing developed and developing countries and economies

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in transition. Extra effort may be required to identify the best talent in developing countries that have historically not been fully engaged because of economic issues or the structure of the community of experts. In both international and national contexts, equity issues need to be considered. Experts can be drawn from both the scientific community and a variety of stakeholder groups, but they should be chosen based on their expertise in areas relevant to the assessment and their ability to participate objectively and constructively in the process. The selection process must be open and transparent, with well-articulated criteria for selection.

Recommendation: A strategy for identifying and engaging appropriate stakeholders should be included in the assessment design to balance the advantages of broad participation with efficiency and credibility of the process.

Capacity Building

Capacity building to develop a common language and technical understanding among stakeholders can greatly enhance the effectiveness of assessments. Not all stakeholders will be familiar with the science or the policy context of a particular assessment, thereby limiting their ability to engage in the process. Decision makers may not be conversant in the relevant science. Scientists and other expert participants may need assistance in communicating effectively with experts from other disciplines and with other stakeholders. Meaningful engagement with the public may also require a degree of capacity building and iterative learning between the "experts" and the public to arrive at a shared set of facts and a focus on issues that are of clear importance to the stakeholders (NRC 1996; Farrell et al. 2001). It is imperative that the engagement be viewed as a "two-way" communication, since the "experts" often have much to learn about impacts, vulnerability, and perceptions as well as data sources and local knowledge of systems (NRC 1996; Jacobs 2002).

Some assessments have involved successful capacity-building activities. In some regions and sectors, the NACCI succeeded in bringing new stakeholders into the global change arena and providing them with sufficient information to truly engage in the process. The ACIA also included effective capacity building, benefiting from the insights and methods developed by the Global Environmental Assessment project. Important lessons incorporated in the ACIA process include the realization that the assessment process itself was part of the outcome. Similarly, the stratospheric ozone assessments continued to improve on their communication and outreach products, resulting in very sophisticated reports and graphics in later assessments. These examples illustrate the importance of evaluating assessment processes and

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building on prior experiences. A systematic effort is required to improve assessments in the future by drawing lessons from past experience and by developing assessment methodologies and tools. Capacity building should therefore include research support for improving assessment methodologies as well as ensuring that the assessment leadership and participants are familiar with the most recent assessment methodologies and tools.

Investments in capacity building can have payoffs in multiple areas, including (1) expanding the informed audience for the assessment, (2) contributing to future assessment effectiveness, (3) expanding the ability of decision makers to act on scientific information, (4) equipping participants with new knowledge in assessment methodology and tools, and (5) building a scientific community that is more sensitive to needs and concerns of the broader society. In some cases the value of the assessment process, which may involve considerable time commitments on the part of participants, might not be immediately apparent. Thus, additional effort may be required to communicate the benefits and to structure the questions and process such that they are relevant to the participants the assessment aims to engage.

Private-sector participation has been noted as a serious deficiency in multiple U.S. and international assessments. Because engaging business interests has historically been very challenging, special considerations are required to successfully engage private-sector participants. The success of the TEAP has clearly demonstrated the great benefit from designing a process that engages the private sector. Developing a strategy to encourage its participation requires consideration of its decision-making context and business needs. Face-to-face meetings are expensive in terms of time and money, and the connection to either short- or long-term benefits needs to be clear. The global change community needs to be strategic about constructive and creative ways of engagement with the private sector. This might be accomplished by conducting workshops for particular sectors, focused on their concerns, such as identifying economic risks and opportunities and "news you can use," and through web-based communication techniques.

Recommendation: Capacity-building efforts for diverse stakeholders and assessment participants from various disciplines should be undertaken by CCSP in order to develop a common language and a mutual understanding of the science and the decision-making context. This capacity building may be required to ensure that the most salient questions are being addressed and to meaningfully engage diverse stakeholders in assessment activities.

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Communication Strategy

A communication strategy is fundamental to the success of an assessment: without effective communication, the scholarly effort is diminished. Ideally, communication is a two-way process of education. Only if an assessment's scientific findings are effectively communicated, understood, and accepted by targeted audiences can they optimally inform policies and decisions to address the environmental challenges analyzed in the assessment. Furthermore, the target audience must be able to communicate its information needs to the experts conducting the assessment to guarantee that the relevant questions are being addressed. Communication must, therefore, be regarded as a process, not merely an appendage to a report-writing exercise.

The Enquete Kommission provides an example in which the two-way dialogue is guaranteed by having scientists and politicians involved in the process continuously, thereby also increasing the likelihood of timely delivery of the information. However, the Enquete Kommission's direct involvement of politicians in the process is unlike all other assessments evaluated by the committee. The ACIA exemplifies a more typical approach, where the politicians providing the mandate are not directly engaged. The ACIA is universally recognized for having a well-articulated communication strategy to support the policy-making process. Two important factors contributed to the success of the ACIA's communication strategy: (1) its communication strategy was planned from the initiation throughout the process and carried out beyond the report production phase including dissemination activities targeting a broad range of audiences; and (2) the intended target audience was identified in advance, and tailored communications were produced. The IPCC and the MA are making very extensive use of the Internet. Reports are readily available and easily downloaded, including excellent color graphics. In addition, these reports are available in multiple languages.

The characteristic complexity of the science and the range of scientific uncertainties add to the communication challenge. There is often an inherent conflict between scientists' penchant for exactitude and the effective presentation of an environmental assessment to a nontechnical audience (Johnson and Slovic 1995; Johnson 2003). This challenge must be addressed through conscious efforts to simplify language, tables, and scenarios to make them more understandable and to illustrate difficult concepts creatively, particularly when designing dissemination products aimed at the general public. The report should avoid academic jargon and be crafted for easy accessibility. Extreme care must be exercised, however, that any simplified text prepared for differing audiences does not conflict with the more scientific presentations designed for the assessment's original sponsor.

The ozone assessments have grown increasingly sophisticated over time in their communication approaches and in simplifying their message. From

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the 1985 assessment, which did not even include an executive summary, subsequent assessments evolved to produce reports with carefully prepared summaries, viewgraphs, talking points, and nontechnical publications (e.g., Common Questions About Ozone) that summarize current knowledge in commonsense terms and (implicitly) address any current attempts to mislead or obscure the consensus.

Executive summaries are one of the most crucial elements for the successful impact of the assessment exercise on policy and decision making. It should be concise, value-free, and clear about assumptions and uncertainties, and should be crafted and reviewed with attention to clarity, substance, relevance, absence of jargon, and the differing needs of policy and decision makers—recognizing that they are generally not specialists.

Recommendation: Assessments should have a comprehensive, multifaceted communication strategy from the start, encompassing an analysis of the potential audiences, ranging from those requesting the assessment to the general public; use multiple modes of engaging them; focus on the decisions the assessment intends to inform (e.g., policy decisions, legislation, technological innovation, standards, international treaties); and include appropriate dissemination activities.

LEADERSHIP AND ORGANIZATIONAL STRUCTURE

The management structure tends to vary from assessment to assessment. The NACCI established the National Assessment Synthesis Team (NAST) made up of experts from industry, academia, government laboratories, and nongovernmental organizations. The NAST, with its three co-chairmen, had substantial authority to guide the process, and their guidance was critical to the successes of the NACCI. The ACIA established a management structure consisting of various steering committees and local secretariats. The ACIA also benefited from having leadership with substantial understanding of the ability to incorporate lessons learned from previous assessment processes. Major decisions of the IPCC are taken by the plenary of government representatives, which elects 30 chairs and vice-chairs who make up the IPCC bureau. Each working group is supported by a technical support unit, and the overall Bureau is supported by a secretariat. The leadership in the ozone assessment was particularly effective due to both familiarity with the scientific issue and the political awareness necessary to communicate the scientific findings effectively (NRC 2005).

The need for a strong leadership structure is self-evident and was a common thread running through the committee's discussions with those responsible for conducting assessments. A general principle is that the decision-making structure within the assessment needs to be well articulated

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from the outset. However, identifying the appropriate leadership is challenging, and the committee concurs with the findings of the National Research Council (NRC 2005) on the characteristics of good leadership:

> [Good leaders] are committed to progress and are capable of articulating a vision, entraining strong participants, promoting partnerships, recognizing and enabling progress, and creating institutional and programmatic flexibility. Good leaders facilitate and encourage the success of others. They are vested with authority by their peers and institutions, through title, an ability to control resources, or other recognized mechanisms. Without leadership, programmatic resources and research efforts cannot be directed and then redirected to take advantage of new scientific, technological, or political opportunities. (p. 48)

The choice of leadership structures and individuals may not be straightforward, but it is crucial to the success of the endeavor, with significant implications for how effectively the assessment is conducted and how well it is received by the target audience and other stakeholders. Effective assessment leaders respond easily to a changing political environment, provide transparent and legitimate rationale for such a response, and provide consistent messages to participants. In the best of circumstances, individuals with appropriate scientific credentials will naturally emerge, who enjoy the confidence of both the political and the scientific communities, have experience in conducting successful assessments, and are willing to undertake the present one. Since the leaders commonly function as spokespeople for the process, decisions regarding leadership must consider implications for perceptions of objectivity, credibility, and legitimacy.

Recommendation: The leadership and organizational structure of the assessment should be made clear, and the responsibilities of individuals and organizations well articulated.

INTEGRATED ASSESSMENTS

Degree and Nature of Integration

Although multiple definitions of integrated assessments are being used by the community, the committee considers such assessments to result from a process that integrates social, biological, and physical sciences and engineering and allows interdisciplinary synthesis and analysis. Some integrated assessments are integrated after the fact, like the IPCC, and some are actually interdisciplinary and integrated from the beginning, such as the MA. Others, following a more restrictive use of the definition of integrated assessment, comprise a model that explicitly links the dynamics of

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social, biological, and physical systems. All types allow understanding of complex interlinked phenomena and their implications, as well as building a stronger fabric for decision making. However, a well-integrated assessment is difficult to undertake, and managing them is far more difficult than is generally recognized.

The IPCC is one of the few examples of an attempt at integrated assessment; however, it still develops core science findings in separate teams from the impact and response assessments. The requirement that the IPCC draw only on the peer-reviewed literature has increased its scientific credibility, but at the price of making the integration effort slower and less flexible. In synthesizing information from the literature it is difficult to tell whether the individual pieces are based on a set of common assumptions. To some extent the IPCC can address this problem by reviewing the results of integrated assessments conducted by individual research teams. In addition, difficulties in integrating across the three working groups also stem from the distinct paradigms each is working with. Another issue with integrated assessments is the difficulty of developing a common language between different disciplines, particularly between social and natural scientists. As mentioned before, such difficulties can be overcome if resources are devoted to capacity building and development of a common language between the various disciplines. These problems raise concerns about whether integrated assessments of global change can be conducted effectively at the international level.

Because a fully integrated assessment is much more complex and difficult to achieve than assessment of a single issue, there has to be a clear reason why this approach is undertaken. The effectiveness of the early stratospheric ozone assessments in informing decisions demonstrates that not all assessments need to be fully integrated, although there are many benefits to working toward an integrated approach, including greatly enhanced potential to be policy relevant. An alternative approach is "nesting" specific assessments in a broader matrix to provide for a clear focus and illustrative examples at the smaller scale while allowing for generalized lessons in the larger frame. For example, an integrated assessment model may be much more easily developed around a specific decision-making process at a regional scale, such as water resource management. Consider the challenge of providing a credible assessment of the impact of climate change on a specific watershed in which the objective is to assess the availability of future water resources. The nature of climate projections, including the factors that control the spatial and temporal character of precipitation and evaporation are essential, but insufficient to define future water availability. For example, land-use and land-cover change will also have substantial impact on runoff and evaporation rates, and changes in the character of human waste streams (both air- and waterborne) will substantially influence water quality. Our ability to examine future water resource availability

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requires an integrated assessment because the impacts and decisions that influence water are place-based, but the drivers of these impacts are also drawn from a much larger scale (e.g., climate change). Such an integrated assessment can best be completed with a "matrix" or "nested" approach, in which the large-scale drivers (e.g., scenarios or projections for future climate change) become one element of the assessment process that can serve as a foundation for a series of other regional or sector assessments. At a regional scale, the vast amount of place-based information, including the additional drivers (e.g., land-use change), can be incorporated into the analysis to provide a more comprehensive treatment of potential changes in water quality and quantity. Such an approach might include the use of regionally based mesoscale models that better address the spatial character of the watershed, detailed watershed models, regional observing and information systems, and projections of population growth and the evolution of human systems.

Such a model can be used to illustrate both impacts and response options, and lessons from that model may be applied to other scales or decision-making processes. The degree and nature of the integration of the assessment represents a design decision that should be made with specific reference to the user's needs and the purpose of the assessment. This approach is one way to ensure that broad-scale assessments can continue to be developed, while at the same time enhancing the relevance in individual applications where many resource decisions are made.

Recommendation: The degree and nature of interdisciplinary integration of assessments should be chosen with specific reference to the users and purpose of the assessment and the resources needed to do integrated assessments well. Because fully integrated assessments are more readily done at a specific local decision-making scale, attempts should be made to nest them within a global assessment, which may not need to be fully integrated.

Importance of Integrated Assessments for CCSP

The assessment activities mandated by the 1990 GCRA necessitate some degree of integration in that the act requires reporting on the state of scientific understanding of global change, the effects of global change on a range of sectors, and future trends. It is not clear whether the 21 Synthesis and Assessment Products currently being conducted by CCSP to address this mandate will meet the needs of policy makers in the same way that a more integrated approach might. In particular, integrated assessments have the potential to better link understanding of global change phenomena with their impacts, thereby providing better information for decision making. At the same time, the committee recognizes that integrated assessments are

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challenging. Incorporating a more integrated approach into some of CCSP's assessment activities could provide an important opportunity to learn more about how to conduct more effective integrated assessments, while also producing integrated, societally relevant outcomes.

Recommendation: The CCSP should invest in experimental applications of integrated assessments, with a specific focus on advising future applications of truly integrated, ongoing, interdisciplinary assessments in the United States.

TREATMENT OF UNCERTAINTY

One of the most difficult tasks in an assessment is the expression of uncertainty. In the case of climate change, uncertainties remain as part of the evolving understanding of various aspects of the greenhouse effect, its likely consequences, and the efficacy of various countermeasures. Some of these uncertainties will not be resolved for decades, if then. An effective characterization of uncertainty in assessments requires determining what kinds of uncertainty information would be useful for decision makers as well as developing quantitative or qualitative measures of uncertainty. While there is evidence that decision makers have an aversion to ambiguity, uncertainty is unavoidable in many decision-making contexts. Once decision makers understand that they are operating in an uncertain environment, they typically prefer that the conclusions of an assessment be accompanied by a description of the level and source of relevant uncertainties. The manner in which uncertainties are acknowledged and characterized will affect both the salience and the credibility of the assessment.

Ways of addressing uncertainty include clearly identifying the uncertainties; characterizing and identifying the source and magnitude of the uncertainties; expert judgments of the level of confidence; and testing this sensitivity through the development of plausible future scenarios. For example, the IPCC has attempted to deal with uncertainty by using words to indicate judgment estimates of confidence (e.g., "virtually certain" denotes a greater than 99 percent chance that a result is true, "very likely" denotes a 90-99 percent chance, etc.). Alternatively, there are formal methods for eliciting expert judgments (Morgan and Henrion 1990), but these can be quite time consuming and, therefore, can only be applied selectively.

Recommendation: Uncertainties should be well articulated in global change assessments to the extent they are understood, and the sources of the uncertainty should be described. There should be a deliberate effort to clarify the importance of alternative assumptions and to illustrate the impacts of uncertainties.

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A CREDIBLE AND INDEPENDENT REVIEW PROCESS

Assessments differ from more standard scientific publications, and therefore the typical science peer-review process needs modification. Assessments build on prior knowledge; identify recent advances and research needs; attempt to reach consensus on scientific debates; and in some cases, provide response options, including policy options. Because assessments may include policy-relevant information and even some value judgments in the case of impact assessments, assessment reviews need to be conducted to achieve salience, legitimacy, and credibility. In contrast, typical science peer review focuses solely on scientific credibility. Therefore, the review process should be consistent with the goals of the assessment and the type of assessment. For process assessments that focus only on the scientific understanding of the process, an expert peer review may suffice. However, assessments providing decision support or policy options, such as impact and response assessments, may require a broader review, involving stakeholders and decision makers, in particular.

Many assessments that the committee examined have well-established review mechanisms. For the IPCC, the review process includes a peer review, followed by an expert and government review, and finally a review by the governments who are party to the United Nations Framework Convention on Climate Change. The report and the various summaries are then subject to acceptance by the governments, which meet in plenary for this approval process. This government review process has raised some issues regarding credibility due to the potential for government interference with the scientific conclusions. In contrast, the ACIA provides a model of how a government review can be conducted successfully without the resulting perception that governments influenced the scientific consensus. The government review process for the ACIA involved scientists, who had the ultimate authority over the scientific conclusions, and government representatives, who were given the editorial authority over policy options. In the example of the TEAP, no external review process was undertaken because all the key players were already involved and the assessment contained proprietary information.

Because a well-designed review process has the potential to greatly enhance broad stakeholder ownership and the quality of the outcome, it is essential to the credibility, salience, and legitimacy of the assessment. As previously mentioned, an assessment review is distinct from a peer review in that it cannot be undertaken solely from the perspective of scientific credibility, but must also focus on issues of salience and legitimacy. The committee found that an effective approach is a staged review, such as employed in the ACIA, beginning with the scientific community, with subsequent involvement of governments and other relevant stakeholders. To ensure that legitimacy and credibility can be enhanced simultaneously, an approach should

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be designed that addresses criticisms regarding government reviews that attempt to alter the report's scientific conclusions inappropriately. This can be addressed by providing clear and transparent guidelines giving experts the ultimate editorial authority over the scientific conclusions in response to government reviews and comments. In addition, neutral review editors from a broad range of disciplines could function as referees to ensure that comments are responded to appropriately and that well-defined guidelines are followed to avoid the perception of government reviews altering scientific conclusions.

Recommendation: An assessment review process should enhance salience and legitimacy in addition to credibility, by engaging interested and affected parties in the review process in addition to the expert community. The design of the review process should be adapted depending on whether it is a process, impact, or response assessment. The use of a well-balanced panel of review editors from a broad range of backgrounds should be considered to ensure that the review comments are responded to appropriately. In addition, a transparent mechanism for a legitimate and credible government review needs to be designed.

DEVELOPING DECISION-SUPPORT APPLICATIONS

Decision-support tools include a wide range of tools and models that link analyses, environmental and social data, and information about decisions and outcomes. They help decision makers understand the sensitivity of relevant systems, assess vulnerability, identify management alternatives, characterize uncertainties, and plan for implementation (Chen et al. 2004; Pyke and Pulwarty 2006). For example, regional tools were developed during the development of the NACCI that allow web-based access to assessment data to assist in making agricultural crop decisions. In its strategic plan (CCSP 2003), the CCSP identified the need for increased efforts to develop decision-support applications, a new emphasis that was lauded in the NRC review of the plan (NRC 2004).

Adaptation to global change in general, and climate change in particular, requires that the institutional context of decisions be recognized in the development of decision-support tools as well as adaptation and mitigation activities. Assessments should be designed to be policy relevant but not policy prescriptive. For example, a response assessment may provide policy options and analysis describing possible policy outcomes but it should not prescribe which response to choose. There are many ways to ensure that decision-support efforts are properly focused and effective, but it will not be possible to support every type of decision at every scale. When selecting specific case studies to be nested within the broader assessment activity,

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CCSP needs to be strategic about the kinds of decisions to support and the scale at which such support is most urgently needed. It is also important that sufficient resources be dedicated to supporting the development of decision-support tools, which is a relatively new area of emphasis for CCSP (NRC 2004). The critical issue in decision support is to provide useful, policy-neutral information targeted for use in particular sectors and for specific applications.

For assessments intended to inform national- and international-level decisions about how to effectively manage the climate change risk, the information is being applied to issues that are apt to be highly politically charged. Thus, CCSP needs to be thoughtful about how it supports development of decision-support tools so that the information resulting from such tools is credible. The area of cost-benefit analysis is particularly challenging; for example, the IPCC has struggled with whether to conduct such analyses as part of the assessment or instead to synthesize existing analyses conducted by others. Some options would be for CCSP to (1) support the development of the needed decision-support tools; (2) encourage the appropriate science or modeling community to focus their efforts on the needs of policy makers, and then synthesize the results in a manner that will be useful to the policy-making community; or (3) commission the development and application of the requisite decision-support tools as part of the assessment process itself. An example of the third option is CCSP Synthesis and Assessment Product 2.1, in which existing tools are being used to develop new emission scenarios, analyze their impact on the energy system, and assess the costs to the economy.

Recommendation: CCSP should foster and support the development of knowledge systems that effectively build connections between those who generate scientific information and the decision makers who are most likely to benefit from access to the knowledge that is generated. One approach is to support the development of decision-support tools and applications at various scales of decision making that can be used in the context of assessments. In doing so the CCSP should identify decision-making processes of high priority or broad application that address key regional or sectoral vulnerabilities, and then evaluate the decision-support needs in those applications. New analytical and predictive tools can then be devised that have direct benefits in specific assessment applications.

EMPLOYING A NESTED MATRIX APPROACH

Adaptive approaches are needed to continually integrate advances in knowledge into the policy context. Although it would be ideal to address each sector and region at the local, regional, and national scales while

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assessing impacts and responses, it is unlikely that sufficient resources will be available to do this comprehensively on an ongoing basis. One way to address the resource issues associated with assessment is to build a broad conceptual framework or matrix linked to smaller-scale illustrative examples. For example, an assessment could be conducted at a national level, accompanied by selected localized case studies of impacts on specific sectors or implications for specific local decision making. The work on the broad themes and trends can be an ongoing effort, while individual, integrated, local, or sectoral assessments can be nested strategically in the broader research agenda. This will help develop an ongoing assessment program that has more coherence over time.

An example of the application of the nested matrix approach is using global climate models to identify likely future changes in temperature and precipitation at the national and regional level that may result from climate change. By connecting such outputs to hydrologic models, it is possible to identify a range of likely impacts on runoff for specific watersheds and evaluate potential vulnerabilities for regions and sectors. Based on that information, specific regions or sectors that are identified as areas of high vulnerability can be selected for a more focused integrated assessment that includes the demographic and institutional context as well as physical parameters. At a regional scale, the vast amount of place-based information, including additional drivers (e.g., land-use change), can be incorporated into the analysis to provide a more comprehensive treatment of potential changes in water quality and quantity.

Recommendation: CCSP should consider implementing a nested matrix concept in developing subsequent assessments.

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Appendixes

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A

Statement of Task

An ad hoc committee will seek to identify lessons learned from past assessments to guide future global change assessment activities of the U.S. Climate Change Science Program (CCSP). The study will be approached in two steps.

1. The committee will conduct a comparative analysis of past assessments that have stated objectives similar to those of the CCSP. Specifically, the committee will examine the strengths and weaknesses of selected past assessments in the following areas:

- Establishing clear rationales and appropriate institutional structures;
- Designing and scheduling assessment activities;
- Involving the scientific community and other relevant experts in the preparation and review of assessment products;
- Engaging the potential users of assessment products;
- Accurately and effectively communicating scientific knowledge, uncertainty, and confidence limits;
- Guiding plans for future global change research activities, including observation, monitoring, and modeling of past and future changes; and
- Creating assessment products that are valued by their target audiences.

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2. The committee will identify approaches (in terms of geographic scale, scope, assessment entity, and timing) and products that are most effective for meeting the CCSP's stated objectives for assessments.

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B

U.S. Global Change Research Act of 1990 Public Law 101-606 [S.169]

An Act to require the establishment of a United States Global Change Research Program aimed at understanding and responding to global change, including the cumulative effects of human activities and natural processes on the environment, to promote discussions toward international protocols in global change research, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Global Change Research Act of 1990".

SEC. 2. DEFINITIONS.

As used in this Act, the term—

1. "Committee" means the Committee on Earth and Environmental Sciences established under section 102;
2. "Council" means the Federal Coordinating Council on Science, Engineering, and Technology;
3. "Global change" means changes in the global environment (including alterations in climate, land productivity, oceans or other water resources, atmospheric chemistry, and ecological systems) that may alter the capacity of the Earth to sustain life;

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4. "Global change research" means study, monitoring, assessment, prediction, and information management activities to describe and understand—

   A. the interactive physical, chemical, and biological processes that regulate the total Earth system;
   B. the unique environment that the Earth provides for life;
   C. changes that are occurring in the Earth system; and
   D. the manner in which such system, environment, and changes are influenced by human actions;

5. "Plan" means the National Global Change Research Plan developed under section 104, or any revision thereof; and
6. "Program" means the United States Global Change Research Program established under section 103.

TITLE I—
UNITED STATES GLOBAL CHANGE RESEARCH PROGRAM

SEC. 101. FINDINGS AND PURPOSE.

(a) FINDINGS.—The Congress makes the following findings:

1. Industrial, agricultural, and other human activities, coupled with an expanding world population, are contributing to processes of global change that may significantly alter the Earth habitat within a few human generations.
2. Such human-induced changes, in conjunction with natural fluctuations, may lead to significant global warming and thus alter world climate patterns and increase global sea levels. Over the next century, these consequences could adversely affect world agricultural and marine production, coastal habitability, biological diversity, human health, and global economic and social well-being.
3. The release of chlorofluorocarbons and other stratospheric ozone-depleting substances is rapidly reducing the ability of the atmosphere to screen out harmful ultraviolet radiation, which could adversely affect human health and ecological systems.
4. Development of effective policies to abate, mitigate, and cope with global change will rely on greatly improved scientific understanding of global environmental processes and on our ability to distinguish human-induced from natural global change.
5. New developments in interdisciplinary Earth sciences, global observing systems, and computing technology make possible significant

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advances in the scientific understanding and prediction of these global changes and their effects.

6. Although significant Federal global change research efforts are underway, an effective Federal research program will require efficient interagency coordination, and coordination with the research activities of State, private, and international entities.

(b) PURPOSE.—The purpose of this title is to provide for development and coordination of a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.

SEC. 102. COMMITTEE ON EARTH AND ENVIRONMENTAL SCIENCES.

(a) ESTABLISHMENT.—The President, through the Council, shall establish a Committee on Earth and Environmental Sciences. The Committee shall carry out Council functions under section 401 of the National Science and Technology Policy, Organization, and Priorities Act of 1976 (42 U.S.C. 6651) relating to global change research, for the purpose of increasing the overall effectiveness and productivity of Federal global change research efforts.

(b) MEMBERSHIP.—The Committee shall consist of at least one representative from—

1. the National Science Foundation;
2. the National Aeronautics and Space Administration;
3. the National Oceanic and Atmospheric Administration of the Department of Commerce;
4. the Environmental Protection Agency;
5. the Department of Energy;
6. the Department of State;
7. the Department of Defense;
8. the Department of the Interior;
9. the Department of Agriculture;
10. the Department of Transportation;
11. the Office of Management and Budget;
12. the Office of Science and Technology Policy;
13. the Council on Environmental Quality;
14. the National Institute of Environmental Health Sciences of the National Institutes of Health; and
15. such other agencies and departments of the United States as the President or the Chairman of the Council considers appropriate.

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Such representatives shall be high ranking officials of their agency or department, wherever possible the head of the portion of that agency or department that is most relevant to the purpose of the title described in section 101(b).

(c) CHAIRPERSON.—The Chairman of the Council, in consultation with the Committee, biennially shall select one of the Committee members to serve as Chairperson. The Chairperson shall be knowledgeable and experienced with regard to the administration of scientific research programs, and shall be a representative of an agency that contributes substantially, in terms of scientific research capability and budget, to the Program.

(d) SUPPORT PERSONNEL.—An Executive Secretary shall be appointed by the Chairperson of the Committee, with the approval of the Committee. The Executive Secretary shall be a permanent employee of one of the agencies or departments represented on the Committee, and shall remain in the employ of such agency or department. The Chairman of the Council shall have the authority to make personnel decisions regarding any employees detailed to the Council for purposes of working on business of the Committee pursuant to section 401 of the National Science and Technology Policy, Organization, and Priorities Act of 1976 (42 U.S.C. 6651).

(e) FUNCTIONS RELATIVE TO GLOBAL CHANGE.—The Council, through the Committee, shall be responsible for planning and coordinating the Program. In carrying out this responsibility, the Committee shall—

1. serve as the forum for developing the Plan and for overseeing its implementation;
2. improve cooperation among Federal agencies and departments with respect to global change research activities;
3. provide budgetary advice as specified in section 105;
4. work with academic, State, industry, and other groups conducting global change research, to provide for periodic public and peer review of the Program;
5. cooperate with the Secretary of State in—

   (A) providing representation at international meetings and conferences on global change research in which the United States participates; and
   (B) coordinating the Federal activities of the United States with programs of other nations and with international global change research activities such as the International Geosphere-Biosphere Program;

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6. consult with actual and potential users of the results of the Program to ensure that such results are useful in developing national and international policy responses to global change; and
7. report at least annually to the President and the Congress, through the Chairman of the Council, on Federal global change research priorities, policies, and programs.

SEC. 103. UNITED STATES GLOBAL CHANGE RESEARCH PROGRAM.
The President shall establish an interagency United States Global Change Research Program to improve understanding of global change. The Program shall be implemented by the Plan developed under section 104.

SEC. 104. NATIONAL GLOBAL CHANGE RESEARCH PLAN.
(a) IN GENERAL.—The Chairman of the Council, through the Committee, shall develop a National Global Change Research Plan for implementation of the Program. The Plan shall contain recommendations for national global change research. The Chairman of the Council shall submit the Plan to the Congress within one year after the date of enactment of this title, and a revised Plan shall be submitted at least once every three years thereafter.

(b) CONTENTS OF THE PLAN.—The Plan shall—

1. establish, for the 10-year period beginning in the year the Plan is submitted, the goals and priorities for Federal global change research which most effectively advance scientific understanding of global change and provide usable information on which to base policy decisions relating to global change;
2. describe specific activities, including research activities, data collection and data analysis requirements, predictive modeling, participation in international research efforts, and information management, required to achieve such goals and priorities;
3. identify and address, as appropriate, relevant programs and activities of the Federal agencies and departments represented on the Committee that contribute to the Program;
4. set forth the role of each Federal agency and department in implementing the Plan;
5. consider and utilize, as appropriate, reports and studies conducted by Federal agencies and departments, the National Research Council, or other entities;
6. make recommendations for the coordination of the global change research activities of the United States with such activities of other nations and international organizations, including—

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(A) a description of the extent and nature of necessary international cooperation;
(B) the development by the Committee, in consultation when appropriate with the National Space Council, of proposals for cooperation on major capital projects;
(C) bilateral and multilateral proposals for improving worldwide access to scientific data and information; and
(D) methods for improving participation in international global change research by developing nations; and

7. estimate, to the extent practicable, Federal funding for global change research activities to be conducted under the Plan.

(c) RESEARCH ELEMENTS.—The Plan shall provide for, but not be limited to, the following research elements:

1. Global measurements, establishing worldwide observations necessary to understand the physical, chemical, and biological processes responsible for changes in the Earth system on all relevant spatial and time scales.
2. Documentation of global change, including the development of mechanisms for recording changes that will actually occur in the Earth system over the coming decades.
3. Studies of earlier changes in the Earth system, using evidence from the geological and fossil record.
4. Predictions, using quantitative models of the Earth system to identify and simulate global environmental processes and trends, and the regional implications of such processes and trends.
5. Focused research initiatives to understand the nature of and interaction among physical, chemical, biological, and social processes related to global change.

(d) INFORMATION MANAGEMENT.—The Plan shall provide recommendations for collaboration within the Federal Government and among nations to—

1. establish, develop, and maintain information bases, including necessary management systems which will promote consistent, efficient, and compatible transfer and use of data;
2. create globally accessible formats for data collected by various international sources; and
3. combine and interpret data from various sources to produce information readily usable by policy makers attempting to formulate effective

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strategies for preventing, mitigating, and adapting to the effects of global change.

(e) NATIONAL RESEARCH COUNCIL EVALUATION.—The Chairman of the Council shall enter into an agreement with the National Research Council under which the National Research Council shall—

1. evaluate the scientific content of the Plan; and
2. provide information and advice obtained from United States and international sources, and recommended priorities for future global change research.

(f) PUBLIC PARTICIPATION.—In developing the Plan, the Committee shall consult with academic, State, industry, and environmental groups and representatives. Not later than 90 days before the Chairman of the Council submits the Plan, or any revision thereof, to the Congress, a summary of the proposed Plan shall be published in the Federal Register for a public comment period of not less than 60 days.

SEC. 105. BUDGET COORDINATION.

(a) COMMITTEE GUIDANCE.—The Committee shall each year provide general guidance to each Federal agency or department participating in the Program with respect to the preparation of requests for appropriations for activities related to the Program.

(b) SUBMISSION OF REPORTS WITH AGENCY APPROPRIATIONS REQUESTS.—

1. Working in conjunction with the Committee, each Federal agency or department involved in global change research shall include with its annual request for appropriations submitted to the President under section 1108 of title 31, United States Code, a report which—

   (A) identifies each element of the proposed global change research activities of the agency or department;
   (B) specifies whether each element (i) contributes directly to the Program or (ii) contributes indirectly but in important ways to the Program; and
   (C) states the portion of its request for appropriations allocated to each element of the Program.

2. Each agency or department that submits a report under paragraph (1) shall submit such report simultaneously to the Committee.

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(c) CONSIDERATION IN PRESIDENT'S BUDGET.—

1. The President shall, in a timely fashion, provide the Committee with an opportunity to review and comment on the budget estimate of each agency and department involved in global change research in the context of the Plan.
2. The President shall identify in each annual budget submitted to the Congress under section 1105 of title 31, United States Code, those items in each agency's or department's annual budget which are elements of the Program.

SEC. 106. SCIENTIFIC ASSESSMENT.

On a periodic basis (not less frequently than every 4 years), the Council, through the Committee, shall prepare and submit to the President and the Congress an assessment which—

1. integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings;
2. analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and
3. analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

SEC. 107. ANNUAL REPORT

[see note]

(a) GENERAL.—Each year at the time of submission to the Congress of the President's budget, the Chairman of the Council shall submit to the Congress a report on the activities conducted by the Committee pursuant to this title, including—

1. a summary of the achievements of the Program during the period covered by the report and of priorities for future global change research;
2. an analysis of the progress made toward achieving the goals of the Plan;
3. expenditures required by each agency or department for carrying out its portion of the Program, including—

    (A) the amounts spent during the fiscal year most recently ended;

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(B) the amounts expected to be spent during the current fiscal year; and

(C) the amounts requested for the fiscal year for which the budget is being submitted.

(b) RECOMMENDATIONS.—The report required by subsection (b)[sic] shall include recommendations by the President concerning—

1. changes in agency or department roles needed to improve implementation of the Plan; and
2. additional legislation which may be required to achieve the purposes of this title.

SEC. 108. RELATION TO OTHER AUTHORITIES.

(a) NATIONAL CLIMATE PROGRAM RESEARCH ACTIVITIES.— The President, the Chairman of the Council, and the Secretary of Commerce shall ensure that relevant research activities of the National Climate Program, established by the National Climate Program Act (15 U.S.C. 2901 et seq.), are considered in developing national global change research efforts.

(b) AVAILABILITY OF RESEARCH FINDINGS.—The President, the Chairman of the Council, and the heads of the agencies and departments represented on the Committee, shall ensure that the research findings of the Committee, and of Federal agencies and departments, are available to—

1. the Environmental Protection Agency for use in the formulation of a coordinated national policy on global climate change pursuant to section 1103 of the Global Climate Protection Act of 1987 (15 U.S.C. 2901 note); and
2. all Federal agencies and departments for use in the formulation of coordinated national policies for responding to human-induced and natural processes of global change pursuant to other statutory responsibilities and obligations.

(c) EFFECT ON FEDERAL RESPONSE ACTIONS.—Nothing in this title shall be construed, interpreted, or applied to preclude or delay the planning or implementation of any Federal action designed, in whole or in part, to address the threats of stratospheric ozone depletion or global climate change.

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TITLE II— INTERNATIONAL COOPERATION IN GLOBAL CHANGE RESEARCH

SEC. 201. SHORT TITLE.
This title may be cited as the "International Cooperation in Global Change Research Act of 1990".

SEC. 202. FINDINGS AND PURPOSES.
(a) FINDINGS.—The Congress makes the following findings:

1. Pooling of international resources and scientific capabilities will be essential to a successful international global change program.
2. While international scientific planning is already underway, there is currently no comprehensive intergovernmental mechanism for planning, coordinating, or implementing research to understand global change and to mitigate possible adverse effects.
3. An international global change research program will be important in building future consensus on methods for reducing global environmental degradation.
4. The United States, as a world leader in environmental and Earth sciences, should help provide leadership in developing and implementing an international global change research program.

(b) PURPOSES.—The purposes of this title are to—

1. promote international, intergovernmental cooperation on global change research;
2. involve scientists and policy makers from developing nations in such cooperative global change research programs; and
3. promote international efforts to provide technical and other assistance to developing nations which will facilitate improvements in their domestic standard of living while minimizing damage to the global or regional environment.

SEC. 203. INTERNATIONAL DISCUSSIONS.
(a) GLOBAL CHANGE RESEARCH.—The President should direct the Secretary of State, in cooperation with the Committee, to initiate discussions with other nations leading toward international protocols and other agreements to coordinate global change research activities. Such discussions should include the following issues:

1. Allocation of costs in global change research programs, especially with respect to major capital projects.

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2. Coordination of global change research plans with those developed by international organizations such as the International Council on Scientific Unions, the World Meteorological Organization, and the United Nations Environment Programme.
3. Establishment of global change research centers and training programs for scientists, especially those from developing nations.
4. Development of innovative methods for management of international global change research, including—

   (A) use of new or existing intergovernmental organizations for the coordination or funding of global change research; and
   (B) creation of a limited foundation for global change research.

5. The prompt establishment of international projects to—

   (A) create globally accessible formats for data collected by various international sources; and
   (B) combine and interpret data from various sources to produce information readily usable by policy makers attempting to formulate effective strategies for preventing, mitigating, and adapting to possible adverse effects of global change.

6. Establishment of international offices to disseminate information useful in identifying, preventing, mitigating, or adapting to the possible effects of global change.

(b) ENERGY RESEARCH.—The President should direct the Secretary of State (in cooperation with the Secretary of Energy, the Secretary of Commerce, the United States Trade Representative, and other appropriate members of the Committee) to initiate discussions with other nations leading toward an international research protocol for cooperation on the development of energy technologies which have minimally adverse effects on the environment. Such discussions should include, but not be limited to, the following issues:

1. Creation of an international cooperative program to fund research related to energy efficiency, solar and other renewable energy sources, and passively safe and diversion-resistant nuclear reactors.
2. Creation of an international cooperative program to develop low cost energy technologies which are appropriate to the environmental, economic, and social needs of developing nations.

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3. Exchange of information concerning environmentally safe energy technologies and practices, including those described in paragraphs (1) and (2).

SEC. 204. GLOBAL CHANGE RESEARCH INFORMATION OFFICE.
Not more than 180 days after the date of enactment of this Act, the President shall, in consultation with the Committee and all relevant Federal agencies, establish an Office of Global Change Research Information. The purpose of the Office shall be to disseminate to foreign governments, businesses, and institutions, as well as the citizens of foreign countries, scientific research information available in the United States which would be useful in preventing, mitigating, or adapting to the effects of global change.

Such information shall include, but need not be limited to, results of scientific research and development on technologies useful for—

1. reducing energy consumption through conservation and energy efficiency;
2. promoting the use of solar and renewable energy sources which reduce the amount of greenhouse gases released into the atmosphere;
3. developing replacements for chlorofluorocarbons, halons, and other ozone-depleting substances which exhibit a significantly reduced potential for depleting stratospheric ozone;
4. promoting the conservation of forest resources which help reduce the amount of carbon dioxide in the atmosphere;
5. assisting developing countries in ecological pest management practices and in the proper use of agricultural, and industrial chemicals; and
6. promoting recycling and source reduction of pollutants in order to reduce the volume of waste which must be disposed of, thus decreasing energy use and greenhouse gas emissions.

TITLE III—GROWTH DECISION AID

SEC. 301. STUDY AND DECISION AID.
(a) The Secretary of Commerce shall conduct a study of the implications and potential consequences of growth and development on urban, suburban, and rural communities. Based upon the findings of the study, the Secretary shall produce a decision aid to assist State and local authorities in planning and managing urban, suburban, and rural growth and development while preserving community character.

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(b) The Secretary of Commerce shall consult with other appropriate Federal departments and agencies as necessary in carrying out this section.
(c) The Secretary of Commerce shall submit to the Congress a report containing the decision aid produced under subsection (a) no later than January 30, 1992. The Secretary shall notify appropriate State and local authorities that such decision aid is available on request.

Approved November 16, 1990.

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C

Climate Change Science Program Synthesis and Assessment Products

In its 2003 strategic plan, the Climate Change Science Program (CCSP) identified 21 synthesis and assessment products that the program would produce (CCSP 2003). The products are listed below, organized by CCSP goals and with the federal agency leading each effort in parentheses.

CCSP GOAL 1 Extend knowledge of the Earth's past and present climate and environment, including its natural variability, and improve understanding of the causes of observed changes

Product 1.1 Temperature trends in the lower atmosphere: steps for understanding and reconciling differences (NOAA)
Product 1.2 Past climate variability and change in the Arctic and at high latitudes (USGS)
Product 1.3 Reanalyses of historical climate data for key atmospheric features: implications for attribution of causes of observed change (NOAA)

CCSP GOAL 2 Improve quantification of the forces bringing about changes in the Earth's climate and related systems

Product 2.1 Scenarios of greenhouse gas emissions and atmospheric concentrations and review of integrated scenario development and application (DOE)

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Product 2.2 North American carbon budget and implications for the global carbon cycle (NOAA)
Product 2.3 Aerosol properties and their impacts on climate (NASA)
Product 2.4 Trends in emissions of ozone-depleting substances, ozone layer recovery, and implications for ultraviolet radiation exposure and climate change (NOAA)

CCSP GOAL 3 Reduce uncertainty in projections of how the Earth's climate and related systems may change in the future

Product 3.1 Climate models: an assessment of strengths and limitations for user applications (DOE)
Product 3.2 Climate projections for research and assessment based on emissions scenarios developed through the Climate Change Technology Program (NOAA)
Product 3.3 Climate extremes including documentation of current extremes: prospects for improving projections (NOAA)
Product 3.4 Risks of abrupt changes in global climate (USGS)

CCSP GOAL 4 Understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes

Product 4.1 Coastal elevation and sensitivity to sea-level rise (EPA)
Product 4.2 State of knowledge of thresholds of change that could lead to discontinuities (sudden changes) in some ecosystems and climate-sensitive resources (USGS)
Product 4.3 Analyses of the effects of global change on agriculture, biodiversity, land, and water resources (USDA)
Product 4.4 Preliminary review of adaptation options for climate-sensitive ecosystems and resources (EPA)
Product 4.5 Effects of global change on energy production and use (DOE)
Product 4.6 Analyses of the effects of global change on human health and welfare and human systems (EPA)
Product 4.7 Within the transportation sector, a summary of climate change and variability sensitivities, potential impacts, and response options (DOT)

CCSP GOAL 5 Explore the uses and identify the limits of evolving knowledge to manage risks and opportunities related to climate variability and change

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Product 5.1 Uses and limitations of observations, data, forecasts, and other projections in decision support for selected sectors and regions (NASA)
Product 5.2 Best-practice approaches for characterizing, communicating, and incorporating scientific uncertainty in decision making to be determined
Product 5.3 Decision-support experiments and evaluations using seasonal-to-interannual forecasts and observational data (NOAA)

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D

Climate Change Science Program Guidelines for Producing Its Synthesis and Assessment Products[1]

The CCSP Synthesis and Assessment Products

The U.S. Climate Change Science Program (CCSP) is producing synthesis and assessment products to support informed discussion and decision making regarding climate variability and change by policy makers, resource managers, stakeholders, the media, and the general public. The CCSP participating agencies are coordinating their work to produce these reports, which will integrate research results focused on identified science issues and related questions frequently raised by decision makers. These reports will provide current evaluations of the identified science foundation that can be used for informing public debate, policy development, and operational decisions, and for defining and setting the future direction and priorities of the program. The CCSP products will be considered federal government disseminations, thus they must be prepared in conformance with the provisions of the Data Quality Act (Section 515 of the Treasury and General Government Appropriations Act of 2001). Any agency sponsoring or contributing to the development of a product must certify that the agency's contribution satisfies its Information Quality Guidelines.

Purpose of the Guidelines

The CCSP Strategic Plan sets forth general principles for its approach to preparing synthesis and assessment products:

[1]Available at: *http://www.climatescience.gov/Library/sap/sap-guidelines.htm*.

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- Analyses structured around specific questions
- Early and continuing involvement of stakeholders
- Explicit treatment of uncertainties
- Transparent public review of analysis questions, methods, and draft results
- Adoption of a "lessons learned" approach, building on the ongoing CCSP analyses.

The purpose of this document is to present guidelines that address the three steps in the process of preparing the synthesis and assessment products: developing the prospectus, drafting and revising the document, and final approval and publication of each product. The guidelines set forth the roles of participants and the steps in the process. The guidelines are intended to ensure that

- Independent scientific judgment serves as the guiding force in preparing the products so they are credible
- Scientists, users, and other stakeholders jointly determine the scope of the products so the topics covered are well defined and the information provided is relevant to the needs expressed
- The process of preparing the products is open at every step so the products have legitimacy (i.e., are perceived to have been prepared fairly).

Participants and Their Roles

CCSP Interagency Committee

CCSP was established by the President in 2002 and integrates the U.S. Global Change Research Program and the Climate Change Research Initiative. The CCSP Interagency Committee provides executive direction for the Program, as described in Chapter 16, "Program Management and Review," of the CCSP Strategic Plan. CCSP's Interagency Committee is chaired by the CCSP Director (a Department of Commerce appointee) and includes representatives of 13 participating departments/agencies that have mission or funding responsibilities in climate and global change research, together with liaisons from the Executive Office of the President.[2] Member-

[2]Participating departments and agencies include: Department of Agriculture (USDA), Department of Commerce/National Oceanic and Atmospheric Administration (DOC/NOAA), Department of Defense (DOD), Department of Energy (DOE), Department of Health and Human Services (HHS), Department of the Interior/U.S. Geological Survey (DOI/USGS), Department of State (DOS), Department of Transportation (DOT), Agency for International Development (USAID), Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), and Smithsonian Institution (SI). In

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ship on the CCSP Interagency Committee is joint with the Subcommittee on Global Change Research (SGCR) of the Committee on Environment and Natural Resources (CENR) of the President's National Science and Technology Council (NSTC). The CCSP Interagency Committee has overall responsibility for direction of the program, including compliance with the requirements of the Global Change Research Act of 1990. With respect to the synthesis and assessment products, the CCSP Interagency Committee provides oversight for the process of preparing the products as described in these guidelines.

Lead Agency(ies)/Department(s)

One or more designated CCSP agency(ies) or department(s) will take the lead in producing each product. The lead agency(ies) will be responsible for developing an open and transparent process for soliciting user input, author nomination and selection, expert peer review and public comment, and production/release of the products, as described in these guidelines. To ensure that the products incorporate as much expertise as possible, the lead agency(ies) will be open to the participation of other individuals or entities with relevant expertise and information. The entities can include other government units (federal or nonfederal), Interagency Working Groups of the CCSP or other Federal Programs, international organizations and government units, nongovernmental organizations (NGOs), and other groups.

Lead and Contributing Authors

Lead and contributing authors of the synthesis and assessment products are scientists or individuals with recognized technical expertise appropriate to a product. Lead and contributing authors may be citizens of any country and be drawn from within or outside the federal government (e.g., universities or other public- or private-sector organizations). These individuals shall be acknowledged experts, known through their publication record and relevant accomplishments and contributions to their field. Lead authors are responsible for the content of the synthesis and assessment products that are submitted to the CCSP Interagency Committee for review.

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addition, the Executive Office of the President and other related programs have designated liaisons who participate on the CCSP Interagency Committee: Office of Science and Technology Policy (OSTP), Council on Environmental Quality (CEQ), Office of Management and Budget (OMB), Climate Change Technology Program (CCTP), and Office of the Federal Coordinator for Meteorology (OFCM).

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Interagency Working Groups

The CCSP Interagency Committee coordinates implementation of its activities in support of the Strategic Plan through Interagency Working Groups (IWGs) of program specialists of its participating departments and agencies, as described in Chapter 16, "Program Management and Review," of the CCSP Strategic Plan. IWGs will contribute significantly to the preparation of the synthesis and assessment products because of their expertise in areas related to the products. IWGs may serve as a means for the lead agency(ies) to coordinate preparation of the products with supporting agencies. They may contribute to planning/preparing the prospectuses, scoping, drafting, reviewing, publishing, or disseminating the final product.

Expert Reviewers

Expert reviewers are scientists or individuals with other special expertise appropriate to a product. The expert reviewers will be selected by the lead agency(ies)/departments. As is the case for lead and contributing authors, reviewers may be citizens of any country and be drawn from within or outside the federal government (e.g., universities or other public- or private-sector organizations). These individuals shall be known through their publications and other forms of recognition of their expertise. Expert reviewers will focus on the scientific/technical content of the draft. Employees of the lead agency(ies), lead authors, and other contributors to the product may not serve as expert reviewers for that product. The expert reviewers will be designated through a process described in the prospectus.

Stakeholders

Stakeholders are defined as they are in Chapter 11 of the CCSP Strategic Plan—that is, "Stakeholders are individuals or groups whose interests (financial, cultural, value-based, or other) are affected by climate variability, climate change, or options for adapting to or mitigating these phenomena."[3] Stakeholders participate during the scoping process by providing information that helps define the audience and potential uses of a product. In addition, stakeholders provide comments on the prospectus, and on the product during the public comment period. These comments are expected to focus on how well the product serves its intended purpose or use.

[3]See Box 11-1 ("Working Definitions"), page 112 of the CCSP Strategic Plan.

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National Research Council

The National Academy of Sciences/National Research Council (NRC) will provide advice on an as-needed basis to the lead agency(ies). In the event that issues are identified that require further clarification, the NRC may be asked to provide additional scientific analyses to help bound the uncertainty associated with these issues.

National Science and Technology Council

The NSTC will be responsible for final review and approval of the synthesis and assessment products. Products not cleared by NSTC cannot be released as disseminations of the federal government. Consistent with NSTC procedures, approvals will require written concurrence from all members of the NSTC's CENR. All comments generated through the NSTC review will be addressed by the CCSP Interagency Committee. The CENR membership includes senior officials representing the Executive Office of the President and the 15 federal agencies with significant responsibilities for environment and natural resources programs.

Steps of the Process

Planning the Process and Preparing a Prospectus

1. The lead agency(ies) solicit input from users and other stakeholders, plan preparation of the product, and summarize the proposed process in a draft prospectus. The draft prospectus will address the topics listed in the subsequent section of this document.
2. The CCSP Interagency Committee reviews and approves the draft prospectus for public comment.
3. Expert reviewers and stakeholders review the draft prospectus. The prospectus comment period will last at least 30 days. The draft prospectus comment period will be announced in a Federal Register Notice (FRN) and posted on the CCSP web site.
4. The lead agency(ies) revise the draft prospectus and finalize author recommendations, taking into consideration the comments received.
5. The CCSP Interagency Committee approves the revised prospectus and the lead agency(ies) notify the lead authors.
6. The CCSP Office posts the draft prospectus comments and the final prospectus on the CCSP web site.

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Additional Stakeholder Interactions, if Needed

7. Lead authors may solicit additional input from users and other stakeholders to assist in the development of the product. The process for soliciting this additional input will be open and described in the prospectus. Approaches include workshops, user surveys, telephone and email conferences, and other mechanisms. The processes used will reflect the expected end use of the product. The CCSP Strategic Plan identifies three end uses for CCSP synthesis and assessment products: (1) informing the evolution of the research agenda; (2) supporting adaptive management and planning; and (3) supporting policy formulation. The products with end uses primarily oriented toward the second and third categories are expected to require significant additional input from users to develop a clear understanding of information needs, timing of decisions, consideration of how uncertainty affects decision making, and other issues. The results from additional stakeholder interactions will be publicly available in summary or more extensive forms through publication on the CCSP web site.

Drafting/Reviewing the Products

8. Lead authors prepare the first draft, including a technical section and a summary for interested nonspecialists.

9. The lead agency(ies) organize and facilitate an expert peer review of the first draft according to the process described in the prospectus. The expert peer review will precede the public comment period to ensure that the products are shaped by scientific considerations. The expert peer-review process may range from that used in a scientific journal to a formal review panel convened by the lead agency or recognized external groups such as the NEX. Participants must be qualified scientific/technical experts, as demonstrated by their record of scholarly publication and other accomplishments. Employees of the lead agency(ies), lead authors, and other contributors to the product may not serve as expert reviewers for that product. The prospectus will describe the process for selecting expert reviewers and the expected dates of the review. If the expert peer review is open to all qualified experts, notice will be disseminated on the CCSP web site and through relevant scientific publications, web sites, and other means. All comments submitted during the expert peer review will be publicly available without attribution to the reviewer unless reviewers agree in advance to posting with specific attribution.

10. Lead authors prepare the second draft of the product, taking into consideration the expert peer-review comments. The scientific judgment of the lead authors will determine responses to the comments. The authors will acknowledge significant contributions made by expert reviewers, as applicable.

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11. The lead agency(ies) post the second draft of the product for public comment for not less than 45 days. Any stakeholders (plus experts who participated in the expert peer-review process) may participate in the public comment period for the second draft. This includes governmental and non-governmental entities. The prospectus will include the expected dates of the public comment period. Notice of the public comment period will be disseminated on the CCSP web site, in the Federal Register, and through other publications, web sites, and means as appropriate to the product, to encourage wide public participation in the review. All comments will be publicly available.

12. The lead authors will prepare a third draft of the product, taking into consideration the comments submitted during the public comment period. The scientific judgment of the lead authors will determine responses to the comments.

Approving, Producing, and Releasing the Products

13. Lead agency(ies) submit the third draft of the product and a compilation of comments received to the CCSP Interagency Committee.

14. If the CCSP Interagency Committee review determines that no further action is needed and that the product has been prepared in conformance with these guidelines and the Data Quality Act (including ensuring objectivity, utility, and integrity as defined in 67 FR 8452), they will submit the product to NSTC for approval. If the CCSP Interagency Committee determines that further revision is necessary, their comments will be sent to the lead agency(ies) for consideration and resolution by lead authors.

15. If needed, NRC can be asked to provide additional scientific analysis to bound scientific uncertainty associated with specific issues.

16. Once the CCSP Interagency Committee has determined that the synthesis and assessment report has been prepared in conformance with these guidelines and the Data Quality Act, the Committee will submit it to NSTC for final review and approval. Approval will require the concurrence of all members of the Committee on Environment and Natural Resources. Comments generated during the NSTC review will be addressed by the CCSP Interagency Committee.

17. Once NSTC approval has been obtained and the product is finalized, the lead agency(ies) will produce and release the completed product using a standard format for all CCSP synthesis and assessment products. The final product and the comments received during the expert review and the public comment period will be posted, without attribution (unless specific reviewers agree to attribution), on the CCSP web site.

18. The product will be widely disseminated through the CCSP web site and other mechanisms.

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Contents of the Prospectus

The proposed process for preparing each CCSP synthesis and assessment product will be summarized in a prospectus that will be publicly available. The prospectus for each product will typically be five to ten pages in length (plus appendices with references and biographical information for proposed lead authors) and will address the following points:

- Overview: description of topic, audience, intended use, questions to be addressed, etc.
- Contact information: email and telephone for responsible individuals at the lead and supporting agencies
- Lead authors: required expertise of lead authors and biographical information for proposed lead authors
- Stakeholder interactions: process already used to solicit input from users and other stakeholders, or proposed plans for doing so, including information for those interested in participating in this process
- Drafting: materials to be used in preparing the product
- Review: the processes through which the product will receive expert peer review and public comment, including the process for selecting expert reviewers and the scheduled dates for the expert peer review and public comment periods
- Related activities: description of how preparation of the product will be coordinated with related activities, including other national or international assessment processes (e.g., the Intergovernmental Panel on Climate Change)
- Communications: proposed method of publication and dissemination of the product
- Proposed timeline.

Materials to Be Used

Authors will use the published, peer-reviewed scientific literature in drafting the products. In the rare case that any materials used in preparing a product are not already published in the peer-reviewed literature, the lead agency(ies) must get approval from the CCSP Interagency Committee and these materials must be made available by the lead agency(ies) and/or CCSP Office. The use of any such non-peer-reviewed materials may be questioned by reviewers during the expert review or public comment period. Authors should seek to publish any materials used in preparing drafts of the products.

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Characteristics of the Products

The products will identify disparate views that have significant scientific or technical support. They will also provide confidence levels for key findings, if this is appropriate to the product.

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Biographical Sketches of Committee Members

Dr. Guy P. Brasseur (Chair) was educated at the Free University of Brussels, Belgium, where he earned two engineering degrees: one in physics (1971) and one in telecommunications and electronics (1974). Dr. Brasseur worked for several years at the Belgian Institute for Space Aeronomy, where he developed advanced models of photochemistry and transport in the middle atmosphere. In 1988, Dr. Brasseur moved to NCAR where he became a staff scientist. He became director of the Atmospheric Chemistry Division in 1990. In January 2000, Dr. Brasseur moved to Hamburg, Germany, where he became Director at the Max Planck Institute for Meteorology, and is also Professor at the Universities of Hamburg and Brussels, and the Scientific Director of the German Climate Computer Center. Since January 1, 2002, Dr. Brasseur is the Chair of the Scientific Committee of the IGBP. As Chair of IGBP, Dr. Brasseur also serves on the Joint Scientific Committee of the World Climate Research Program (WCRP) and on the Scientific Committee of the International Human Dimension Program (IHDP) for Global Environmental Changes. In addition to his management tasks, Dr. Brasseur's primary scientific interests relate to global change, climate variability, chemistry-climate relations, biosphere-atmosphere interactions, climate change, stratospheric ozone depletion, global air pollution including tropospheric ozone, and solar-terrestrial relations.

Ms. Katharine L. Jacobs (Vice-chair) is the Executive Director of the Arizona Water Institute, a consortium of the three Arizona state universities focused on water-related research, education, and technology transfer related to

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water supply sustainability. She is also the Deputy Director of the NSF Center for Sustainability of Arid Region Hydrology and Riparian Areas at the University of Arizona, and Professor and Specialist at the Department of Soil, Water and Environmental Science and Water Resources Research Center. She has twenty years of experience as a water manager for the state of Arizona Department of Water Resources. Her research interests include water policy, connecting science and decision making, stakeholder engagement, use of climate information for water management applications, and drought planning. Ms. Jacobs earned her M.L.A. in environmental planning from the University of California, Berkeley. She was a co-author of the National Assessment and part of the National Assessment Synthesis Team, and has served on numerous NRC committees.

Dr. Eric J. Barron is dean of the Jackson School of Geosciences at the University of Texas at Austin. He received his Ph.D. in geophysics from the University of Miami. Dr. Barron has been a fellow and scientist at the National Center for Atmospheric Research, associate professor of marine geology and geophysics at the University of Miami, and director of Penn State's Earth System Science Center and EMS Environment Institute. His research emphasizes global change, specifically numerical models of the climate system and the study of climate change throughout Earth history. Dr. Barron is a fellow of the American Geophysical Union and the American Meteorological Society. He has served on and chaired numerous NRC committees and was chair of the Panel on Climate Variability and Change. He was a coauthor of the National Assessment and part of the National Assessment Synthesis Team (NAST).

Ambassador Richard Benedick is currently senior adviser to the Pacific Northwest National Laboratory–Joint Global Change Research Institute and president of the National Council for Science and the Environment. He has played a major role in global environmental affairs, as chief U.S. negotiator and a principal architect of the historic Montreal Protocol on protection of the ozone layer, and as special adviser to Secretaries-General of both the United Nations Conference on Environment and Development (Rio de Janeiro, 1992) and the International Conference on Population and Development (Cairo, 1994). A career diplomat, Dr. Benedick served in Iran, Pakistan, Paris, Bonn, and Athens, and directed policy formation at the State Department on environment, natural resources, population, health, and development. His acclaimed book *Ozone Diplomacy* (Harvard, 1991, 1998; Kogyo Chosakai, 1999) was selected for a McGraw-Hill anthology of 20th century environmental classics. In 1991 he was elected to the World Academy of Art and Science, and in 2002 to the American Academy of Diplomacy. Among many awards, he received the two highest Presidential

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career public service honors—the Distinguished and Meritorious Service Awards. He holds an A.B. *summa cum laude,* Columbia; an M.A. (honors) in economics, Yale; a D.B.A., Harvard Graduate School of Business Administration; a D.Sc. *honoris causa,* North Carolina State; and was Evans Fellow at Oxford in metaphysical poetry.

Dr. William L. Chameides (NAS) is Professor Emeritus at the School of Earth and Atmospheric Sciences, Georgia Institute of Technology in Atlanta. Dr. Chameides received his Ph.D. from Yale University. He is currently the Chief Scientist at the Environmental Defense. He is a pioneer of the chemistry of ozone "smog." He demonstrated that natural hydrocarbons contribute to smog and established the chemistry that produces ozone pollution over many rural regions in China and the southeastern United States. He was elected to the National Academy of Sciences in 1998 and has served on numerous NRC committees. He was also a co-chair of the North American Research Strategy for Tropospheric Ozone (NARSTO) Synthesis team.

Dr. Thomas Dietz is Professor of Sociology and Crop and Soil Sciences, Director of the Environmental Science and Policy Program, and Assistant Vice President for Environmental Research at Michigan State University. Dr. Dietz is a Fellow of the American Association for the Advancement of Science, and has been awarded the Sustainability Science Award of the Ecological Society of America, the Distinguished Contribution Award of the American Sociological Association Section on Environment, Technology and Society, and the Outstanding Publication Award, also from the American Sociological Association Section on Environment, Technology and Society. His research interests are in human ecology and cultural evolution. His current research examines the human driving forces of environmental change, environmental values and the interplay between science and democracy in environmental issues. He is a contributing author to the Millennium Ecosystem Assessment. Dr. Dietz received a Ph.D. in ecology from the University of California, Davis.

Dr. Patricia Romero Lankao is a Deputy Director Scientist at the Institute for the Study of Society and Environment (ISSE) at UCAR. Previously she was a Professor in the Department of Politics and Culture at the Autonomous Metropolitan University, Campus Xochimilco, in Mexico City, Mexico. Her general field of expertise and interest is the interface of the human dimensions of global environmental change. She has published on issues such as the design of Mexican environmental policy, water policy in Mexico City, environmental perceptions and attitudes towards public environmental strategies and instruments, and vulnerability to climate variability and change among farmers and water users. She is a member of the

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Scientific Steering Committee of the Global Carbon Project sponsored by IHDP, WCRP, and IGBP. In the past few years she has been involved with the Latin American Center of Administration for the Development (CLAD), the International Human Dimensions Program on Global Environmental Change (IHDP) and associated with the 8th Cohort of the Program Leadership for Environment and Development (LEAD), Mexican Chapter. Dr. Romero, a sociologist by training, has two doctoral degrees: a Ph.D. in regional development from the Autonomous Metropolitan University and a Ph.D. in agricultural sciences from the University of Bonn, Germany. She has been a member of the National System of Researchers since 1994. She won a national environmental prize in 1992 (Mención honorífica, Premio Serfín del Medio Ambiente), and has twice shared the Annual Research Prize with her university research group.

Dr. Mack McFarland is Environmental Fellow at DuPont Fluoroproducts. Dr. McFarland received a B.S. in chemistry from the University of Texas at Austin in 1970 and a Ph.D. in chemical physics from the University of Colorado in 1973. From 1974 through 1983, first as a postdoctoral fellow at York University and then as research scientist at the NOAA Aeronomy Laboratory, he planned, conducted, and interpreted field experiments designed to probe the cycles that control atmospheric ozone concentrations. These studies included measurements of gases and processes important to the global climate change issue. In late 1983 he joined the DuPont Company. His primary responsibilities have been in coordinating research programs and assessment and interpretation of scientific information on stratospheric ozone depletion and global climate change as a basis for policy decisions on these global environmental issues. During 1995 and 1996 Dr. McFarland was on loan to the Atmosphere Unit of the United Nations Environment Programme and in 1997 he was on loan to the Intergovernmental Panel on Climate Change (IPCC) Working Group II Technical Support Unit. The value of his contributions to DuPont has been recognized through a C&P Flagship Award, Environmental Respect Awards, and Environmental Excellence Awards. In 1999 he was awarded an individual Climate Protection Award by the U.S. Environmental Protection Agency for his contributions in providing understandable, reliable information to decision makers. Dr. McFarland has served on the NRC Committee Panel for Chemical Science and Technology. He has participated in every major international scientific assessment on stratospheric ozone and global climate change as author, reviewer, or review editor.

Dr. Harold A. Mooney (NAS) is a professor at Stanford University. He received his Ph.D. from Duke University. He was elected to the National Academies of Sciences in 1982. He has demonstrated that convergent evolu-

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tion takes place in the properties of different ecosystems that are subject to comparable climates and has pioneered in the study of resource allocation in plants. He has worked in many of Earth's diverse ecosystems, including the arctic-alpine, the Mediterranean-climate scrub and grasslands, tropical wet and dry forests, and the deserts of the world. Dr. Mooney's research is currently centered on the study of the impact of global changes on ecosystem structure and function. Professor Mooney has received the Mercer Award of the Ecological Society of America and the Merit Award of the Botanical Society of America. He is a member of the National Academy of Sciences, the American Philosophical Society, and the American Academy of Arts and Sciences and a fellow of the American Association for the Advancement of Science. Dr. Mooney was a co-chair of the science panel of the Millennium Ecosystem Assessment and served as chair of the NRC Committee on Global Change.

Dr. Ravi V. Nathan is Senior Vice President with ACE Global Weather. The ACE Group of insurance and reinsurance companies serves a variety of clients around the world, from large multinational corporations to smaller clients in local markets. Dr. Nathan has more than 20 years of experience, most recently serving as the General Manager for Aquila Inc.'s Weather Derivatives Group where he was responsible for the strategic initiatives, overall profitability and day-to-day management of the weather derivatives business. His expertise is related to the relationship of managing weather/climate risk for finance, insurance, and business. In addition to his corporate roles, Dr. Nathan has served as the President of the Weather Risk Management Association. During his tenure the association introduced standardized contracts for weather derivatives and hosted conferences in the United States, Japan, and Europe to bring together global participants in weather risk management. Dr. Nathan earned a B.A. and M.A. in economics from Madras University, an M.B.A. from Xavier Institute of Management, and a Ph.D. in finance from Oklahoma State University. He is also a Chartered Financial Analyst.

Dr. Edward A. Parson is Professor of Law and Professor of Natural Resources and Environment at the University of Michigan. He received his Ph.D. in public policy from Harvard University, where he served on the faculty of the John F. Kennedy School of Government. Dr. Parson's research interests lie in the fields of environmental policy, particularly its international aspects, and negotiations. His recent environmental research has included projects on scientific and technical assessment in international policy making; policy implications of carbon-cycle management; design of international market-based policy instruments; and development of policy exercises, simulation gaming, and related novel methods for assessment and policy analysis. He

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is the author of a series of simulated multiparty negotiation exercises that are used for policy research and executive training in ten countries. He has worked and consulted for the International Institute for Applied Systems Analysis (IIASA), the United Nations Environment Programme (UNEP), the Commission of the European Union, The White House Office of Science and Technology Policy (OSTP), the Office of Technology Assessment of the U.S. Congress (OTA), the U.S. Environmental Protection Agency (EPA), Environment Canada, and the Privy Council Office of the Government of Canada. Dr. Parson was a member of the National Assessment Synthesis Team.

Dr. Richard Richels directs global climate change research at the Electric Power Research Institute (EPRI) in Palo Alto, California. His current research focus is the economics of mitigating greenhouse gas emissions. In previous assignments, he directed EPRI's energy analysis, environmental risk, and utility planning research activities. Dr. Richels has served as a lead author for the Intergovernmental Panel on Climate Change's (IPCC) Second, Third, and Fourth Scientific Assessments and served on the Synthesis Team for the US National Assessment of Climate Change Impacts on the United States. He also served on the Scientific Steering Committee for the US Carbon Cycle Program. He currently serves on the Advisory Committee for Princeton University's Carbon Mitigation Initiative and Carnegie-Mellon University's Center for Integrated Study of the Human Dimensions of Global Change. Dr. Richels received a B.S. degree in physics from the College of William and Mary in 1968. He was awarded an M.S. degree in 1973 and Ph.D. degree in 1976 from Harvard University's Division of Applied Sciences where he concentrated in decision sciences. While at Harvard he was a member of the Energy and Environmental Policy Center.

NRC STAFF

Dr. Claudia Mengelt is a program officer for BASC. She received her M.S. in Biological Oceanography from the College of Oceanic and Atmospheric Sciences at Oregon State University. Her Master's research focused on how chemical and physical parameters in the surface ocean affect Antarctic phytoplankton species composition and the resulting impacts on biogeochemical cycles. She subsequently obtained her Ph.D. in the Marine Sciences from the University of California, Santa Barbara, where she conducted research on the photophysiology of harmful algal species. She joined the full time staff of BASC in the fall of 2005 following a fellowship with the NRC Polar Research Board in the winter of 2005. At the National Academies, she has worked on studies addressing the design of Arctic observing systems, providing strategic guidance for the National Science Foundation's support of

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the atmospheric sciences, and highlighting major scientific accomplishments of Earth observations from space.

Dr. Amanda C. Staudt was a senior program officer with BASC. She received an A.B. in environmental engineering and sciences and a Ph.D. in atmospheric sciences from Harvard University. During her tenure at the National Academies, Dr. Staudt staffed the National Academies review of the U.S. Climate Change Science Program Strategic Plan and the long-standing Climate Research Committee. Dr. Staudt also worked on studies addressing radiative forcing of climate, surface temperature reconstructions, air quality management in the United States, research priorities for airborne particulate matter, the NARSTO Assessment of the Atmospheric Science on Particulate Matter, weather research for surface transportation, and weather forecasting for aviation traffic flow management. In March 2007, she joined the National Wildlife Federation as their climate scientist.

Ms. Elizabeth A. Galinis is a research associate for BASC. After completing her B.S. in marine science from the University of South Carolina in 2001, she received her M.S. in environmental science and policy from Johns Hopkins University in 2007. Since her start at the National Academies in March 2002, Ms. Galinis has worked on studies involving next-generation weather radar (NEXRAD), weather modification, climate sensitivity, climate change, radiative forcings, the Global Energy and Water Cycle Experiment Americas Prediction Project, U.S. future needs for polar icebreakers, and the effects of climate change on federal lands.

Ms. Rachael Shiflett is a senior program assistant with the Polar Research Board. She received a J.D. from Catholic University and a Masters in Environmental Science from Vermont Law School. Ms. Shiflett has coordinated National Research Council studies that produced the reports a Vision for the International Polar Year 2007-2008, International Polar Year 2007-2008 Report of the Implementation Workshop, Toward an Integrated Arctic Observing Network, Analysis of Global Change Assessments: Lessons Learned, and Exploration of Antarctic Subglacial Aquatic Environments: Environmental and Scientific Stewardship.

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Acronyms

ACIA	Arctic Climate Impact Assessment
CBD	Convention on Biological Diversity
CCRI	Climate Change Research Initiative
CCSP	U.S. Climate Change Science Program
CENR	Committee on Environment and Natural Resources
CFC	Chlorofluorocarbon
CIAP	Climatic Impact Assessment Program
EESC	Effective equivalent stratospheric chlorine
EPA	U.S. Environmental Protection Agency
FACA	Federal Advisory Committee Act
FCCSET	Federal Coordinating Council for Science, Engineering, and Technology
GBA	Global Biodiversity Assessment
GCM	General circulation model
GCRA	Global Change Research Act
GCRP	Global Change Research Program
GEA	Global Environmental Assessment
IASC	International Arctic Science Committee
IGBP	International Geosphere-Biosphere Programme

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IPCC	Intergovernmental Panel on Climate Change
IWG	Interagency Working Group
MA	Millennium Ecosystem Assessment
MSU	Microwave Sounding Unit
NACCI	National Assessment of Climate Change Impacts
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NAST	National Assessment Synthesis Team
NGOs	Nongovernmental organizations
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NSTC	National Science and Technology Committee
OSTP	Office of Science and Technology Policy
OTA	Office of Technology Assessment
TEAP	Technology and Economic Assessment Panel
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UV	Ultraviolet
WG	Working Group
WMO	World Meteorological Organization

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