Climate Change Assessments

Review of the Processes and Procedures of the IPCC

Committee to Review the IPCC

InterAcademy Council

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Preface

Since its founding more than 20 years ago, the Intergovernmental Panel on Climate Change (IPCC) can claim many important accomplishments to its credit. First among these are the periodic assessments of our understanding of the nature, origin, and impact of observed changes in the world's climate. Also among its significant contributions has been the sustaining of a global focus on climate change. Indeed IPCC has provided the framework for a continued and rather remarkable international conversation on climate research both among scientists and policymakers. In many ways IPCC, with its massive, far-flung, and decentralized network of scientists along with the governments represented on the Panel, represents a significant social innovation. For these and other contributions the IPCC was one of the recipients of the Nobel Peace Prize in 2007.

In response to some sustained criticism and a heightened level of public scrutiny of the Fourth Assessment Report, the United Nations and IPCC asked the InterAcademy Council (IAC) to assemble a committee to review the processes and procedures of the IPCC and make recommendations for change that would enhance the authoritative nature of the IPCC reports.

Our review was undertaken amidst a flurry of interesting, very public discussions surrounding aspects of IPCC's fourth assessment that raised concerns in some quarters regarding the continuing credibility of the IPCC assessments themselves and the processes and procedures underlying them. Among the critical contributions to this international discourse was a report from the Netherlands Environmental Assessment Agency on issues of concern in the report of Working Group II and the associated Summary for Policy Makers (PBL, 2010). Similar but more muted concerns followed publication of the Third Assessment Report in 2001. On the other hand, many groups of scientists have insisted that whatever the failings in certain aspects of IPCC's massive assessment, the key findings of the most recent IPCC assessment remain, as the Netherlands Environmental Assessment Agency concluded, unaffected. In the United States, the National Research Council came to the same conclusion after the third assessment and again more recently (NRC, 2001, 2010a, b, c).

Scientific debates have always involved controversies over the value and importance of particular classes of evidence, and this can be expected to continue. Moreover, all scientific knowledge always contains some level of uncertainty and any actions based on scientific evidence inevitably involves an assessment of risk and a process of risk management. Finally, given the dependence of major facets of IPCC assessments on vast data collections and complex models whose parameters are especially difficult to assess independently, risk assessments are especially challenging. However, as the resulting controversies gained some momentum, they tended to expand beyond the IPCC assessments and raise issues ranging from the proper role of science [and scientists] in policymaking to the dangers of 'group think' or consensus building as a general proposition.

Unlike much of the current debate, the focus of this review is on the processes and procedures that support and give structure to IPCC's very distinctive assessments. Our task was to broadly

assess the processes and procedures of the IPCC and make recommendations on how they might be improved in order to enhance the quality and authoritative nature of future assessments.

As I consider IPCC as an organization, it seems to me that its large decentralized worldwide network of scientists is the source of both its strength and its continuing vitality. However, climate science has become so central to important public debates that accountability and transparency must be considered as a growing obligation, and this alone would require revisiting IPCC's processes and procedures. In fact IPCC has shown itself to be an adaptive organization in the past in the sense that it has adjusted the processes and procedures surrounding its assessments both in response to scientific developments and as a result of lessons learned over the years. I expect that it will continue to do so and that the fifth assessment is certain to reflect some continuing change. Nevertheless its overall management and governance structure has not been modified, and in my view this has made it less agile and responsive than it needs to be.

The intersection of climate science and public policy is certain to remain a controversial arena for some time as so many competing interests are at stake, including the interests of future generations and the diverse interests of different nations, regions, and sectors of society around the world. Moreover, thoughtful controversy will remain a critical ingredient in stimulating further developments on the scientific frontier relating to our understanding of evolving climate conditions, their impact and the possible responses of policy makers. Indeed climate science is a collective learning process as data are accumulated, interpreted, and used to construct models, and as alternative hypotheses are tested until we have increased confidence in our measurements and models and as a subset of ideas survive careful testing and competing explanations are eliminated. I hope that the progress of climate science in all of these dimensions may slowly remove some of the uncertainties that continue to impede our fuller understanding of global climate change. In my judgment IPCC can continue to remain a very valuable resource, provided it can continue to highlight both what we believe we know and what we believe is still unknown and to adapt its processes and procedures in a manner that reflects both the dynamics of climate science and the needs of public policy for the best possible understanding of changing global climate, its impacts, and possible mitigation initiatives.

Harold T. Shapiro, Chair

IAC Report Review

This report was externally reviewed in draft form by 12 internationally renowned experts chosen for their diverse perspectives, technical knowledge, and geographical representation, in accordance with procedures approved by the IAC Board. The purpose of this independent review was to provide candid and critical comments that would help the IAC to produce a sound report that meets the IAC standards for objectivity, evidence, and responsiveness to the study charge.

The review procedure and draft manuscript remain confidential to protect the integrity of the deliberative process. Although the reviewers provided constructive comments and suggestions, they were not asked to endorse the conclusions and recommendations, nor did they see the final draft of the report before its release.

Reviewers of IAC Report

The IAC thanks the following individuals for their review of this report:

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Monitors of IAC Review Process

The review of this report was overseen by two review monitors. Appointed by the IAC Co-Chairs, the review monitors were responsible for ascertaining that the independent examination of this report was carried out in accordance with IAC procedures and that all review comments

were carefully considered. The IAC thanks the following monitors for their participation in the review process:

Kurt LAMBECK, Past President, Australian Academy of Science; Professor of Geophysics, Australian National University, Canberra, Australia

Ralph CICERONE, President, United States National Academy of Sciences, Washington, DC, USA

Full responsibility for the final content of this report rests entirely with the authoring Committee and the InterAcademy Council.

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Several individuals facilitated the Committee's work in essential ways. Renate Christ, IPCC Secretary, provided the extensive documentation requested by the Committee quickly and in a useful form, and clarified many issues for the Committee in the course of the review. Derek Rector and the Diamax Corporation designed and maintained the Committee's website and communications systems, and provided ongoing support. William Kearney, William Skane, Irene van Houten, Alice Henchley, and Bill Hartnett guided the Committee on public information issues and handled media relations. The Committee greatly appreciates their contributions.

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Executive Summary

Climate change is a long-term challenge that will require every nation to make decisions about how to respond. The Intergovernmental Panel on Climate Change (IPCC) was established by the World Meteorological Organization and the United Nations Environment Programme to help inform such decisions by producing comprehensive assessments of what is known about the physical climate system, its global and regional impacts, and options for adaptation and mitigation. Sitting at the interface between science and politics, the IPCC assessment process has sustained a working dialog between the world's governments and scientists since its inception in 1988. Representatives of 194 participating governments agree on the scope of the assessment, elect the scientific leaders of the assessment, nominate authors, review the results, and approve the summaries written for policy makers. More than a thousand volunteer scientists evaluate the available scientific, technological, and socioeconomic information on climate change, and draft and review the assessment reports. The thousands of scientists and government representatives who work on behalf of the IPCC in this non-traditional partnership are the major strength of the organization.

Through its assessment reports, the IPCC has gained enormous respect and even shared the Nobel Peace Prize in 2007 for informing climate policy and raising public awareness worldwide. However, amidst an increasingly intense public debate over the science, impacts, and cost of climate change, the IPCC has come under heightened scrutiny about its impartiality with respect to climate policy and about the accuracy and balance of its reports. In response, the United Nations and the IPCC commissioned the InterAcademy Council to convene a Committee to review the processes and procedures of the IPCC.

The Committee found that the IPCC assessment process has been successful overall. However, the world has changed considerably since the creation of the IPCC, with major advances in climate science, heated controversy on some climate-related issues, and an increased focus of governments on the impacts and potential responses to changing climate. A wide variety of interests have entered the climate discussion, leading to greater overall scrutiny and demands from stakeholders. The IPCC must continue to adapt to these changing conditions in order to continue serving society well in the future. The Committee's key recommendations for improving IPCC's assessment process are given below.

KEY RECOMMENDATIONS

The Committee's main recommendations relate to governance and management, the review process, characterizing and communicating uncertainty, communications, and transparency in the assessment process. Other detailed recommendations on specific aspects of the assessment process appear in Chapters 2-4, and a complete list of recommendations appears in Chapter 5.

Governance and Management

The complexity and scale of climate change research and the associated assessment task have grown significantly over the last two decades, as have public expectations regarding the assessments. Yet the fundamental management structure of the IPCC has remained largely unchanged. The IPCC management structure comprises the Panel itself, which makes decisions about the structure, principles, procedures, and work program of the IPCC; the Bureau, which is elected by the Panel to oversee the assessment work; and a small Secretariat, which supports the work of the Panel and the Bureau. The Panel makes all of its major decisions at annual Plenary sessions. However, important decisions need to be made more often, and the Bureau has too limited a set of responsibilities and meets too rarely to meet this need.

Many organizations in the public and private sector have addressed the need for ongoing decision making by establishing an Executive Committee to act on their behalf. Similarly, the IPCC should establish an Executive Committee elected by and reporting to the Panel. An IPCC Executive Committee would act on issues—such as approving minor corrections to published reports, approving modest alterations in the scope of an ongoing assessment, ensuring effective communication—and any other task specifically delegated by the Panel. To respond quickly, the Executive Committee should be relatively small with ideally no more than 12 members. Its membership would include selected IPCC leaders as well as individuals from academia, nongovernmental organizations, and/or the private sector who have relevant experience and who are not connected with the IPCC or even climate science. Their participation would improve the credibility and independence of the Executive Committee.

Recommendation: The IPCC should establish an Executive Committee to act on its behalf between Plenary sessions. The membership of the Committee should include the IPCC Chair, the Working Group Co-chairs, the senior member of the Secretariat, and 3 independent members, including some from outside of the climate community. Members would be elected by the Plenary and serve until their successors are in place.

The IPCC Secretariat supports the Panel and Bureau by organizing meetings, communicating with governments, supporting the travel of developing-country scientists, managing the IPCC budget and website, and coordinating report publication and outreach. Although the number of staff has grown from 4 to 10 individuals, the growth in the magnitude and intricacy of the assessment task, advances in digital technologies, and new communications needs (see "Communications" below) have changed the mix of skills required of the Secretariat. An Executive Director is needed to lead the Secretariat, ensure that IPCC protocols are followed, keep in touch with the Working Group Co-chairs, and speak on behalf of the IPCC. As a peer of the Working Group Co-chairs, the individual selected as Executive Director would be capable of acting on behalf of the IPCC Chair. The Executive Director would also be a member of the Executive Committee.

Recommendation: The IPCC should elect an Executive Director to lead the Secretariat and handle day-to-day operations of the organization. The term of this senior scientist should be limited to the timeframe of one assessment.

Review Process

Peer review is an important mechanism for assuring the quality of reports. IPCC's peer review process is elaborate, involving two formal reviews and one or more informal reviews of preliminary text. The first complete draft is formally reviewed by scientific experts nominated by government representatives, observer organizations, and the IPCC Bureau. Lead Authors consider the review comments and prepare the second draft, which is reviewed by the same experts as well as government representatives. Two or more Review Editors for each chapter oversee the review process, ensuring that review comments and controversial issues are handled appropriately. However, the Lead Authors have the final say on the content of their chapter.

With the tight schedule for the revision process, authors do not always consider the review comments carefully, potentially overlooking errors in the draft report that might have been caught. Some errors will be missed in any review process; but with stronger enforcement of existing IPCC review procedures, the number of errors could be minimized. Staff support and clarification about the roles and responsibilities of Review Editors would help them carry out proper oversight.

Recommendation: The IPCC should encourage Review Editors to fully exercise their authority to ensure that reviewers' comments are adequately considered by the authors and that genuine controversies are adequately reflected in the report.

For recent assessments, some governments made the second draft available for review by national experts and other interested parties, considerably opening the review process. Although an open review potentially improves the report by increasing the level of scrutiny and widening the range of viewpoints offered, it also substantially increases the number of review comments. Drafts of the Fourth Assessment Report drew 90,000 review comments (an average of a few thousand comments per chapter), stretching the ability of Lead Authors to respond thoughtfully and fully. A more targeted process for responding to reviewer comments could both ensure that the most significant review issues are addressed and reduce the burden on authors, who currently must document responses to all reviewer comments. In the targeted process envisioned, the Review Editors would prepare a written summary of the most significant review issues. While the Lead Authors would prepare written responses to these issues and all other non-editorial comments, they could focus their attention on the most significant matters.

Recommendation: The IPCC should adopt a more targeted and effective process for responding to reviewer comments. In such a process, Review Editors would prepare a written summary of the most significant issues raised by reviewers shortly after review comments have been received. Authors would be required to provide detailed written responses to the most significant review issues identified by the Review Editors, abbreviated responses to all non-editorial comments, and no written responses to editorial comments.

Characterizing and Communicating Uncertainty

Uncertainty is characterized and communicated by describing how much is known about a topic (i.e., the quality and nature of the evidence available) and the probability that a particular event will occur. Each key conclusion in the Summary for Policy Makers is accompanied by a judgment about its uncertainty. For the fourth assessment, each Working Group used a different variation on IPCC's guidance to describe uncertainty. Working Group I relied primarily on a quantitative likelihood scale (e.g., "extremely likely" indicates a greater than 95 percent probability that a particular event will occur). Working Group II relied primarily on a quantitative confidence scale (e.g., "high confidence" indicates an 8 out of 10 chance of being correct). Working Group III relied exclusively on a qualitative level-of-understanding scale (i.e., understanding is described in terms of the amount of evidence available and the degree of agreement among experts). The level-of-understanding scale is a convenient way of communicating the nature, number, and quality of studies on a particular topic, as well as the level of agreement among studies. It should be used by all Working Groups, as suggested in the IPCC uncertainty guidance for the Fourth Assessment Report.

Recommendation: All Working Groups should use the qualitative level-of-understanding scale in their Summary for Policy Makers and Technical Summary, as suggested in IPCC's uncertainty guidance for the Fourth Assessment Report. This scale may be supplemented by a quantitative probability scale, if appropriate.

The Working Group II Summary for Policy Makers has been criticized for various errors and for emphasizing the negative impacts of climate change. These problems derive partly from a failure to adhere to IPCC's uncertainty guidance for the fourth assessment and partly from shortcomings in the guidance itself. Authors were urged to consider the amount of evidence and level of agreement about all conclusions and to apply subjective probabilities of confidence to conclusions when there was high agreement and much evidence. However, authors reported high confidence in some statements for which there is little evidence. Furthermore, by making vague statements that were difficult to refute, authors were able to attach "high confidence" to the statements. The Working Group II Summary for Policy Makers contains many such statements that are not supported sufficiently in the literature, not put into perspective, or not expressed clearly. When statements are well defined and supported by evidence—by indicating when and under what climate conditions they would occur—the likelihood scale should be used.

Recommendation: Quantitative probabilities (as in the likelihood scale) should be used to describe the probability of well-defined outcomes only when there is sufficient evidence. Authors should indicate the basis for assigning a probability to an outcome or event (e.g., based on measurement, expert judgment, and/or model runs).

Communications

Communicating the results of IPCC assessments is challenging because of the range and complexity of climate science and response options and the increasing need to speak to audiences beyond scientists and governments. The communications challenge has taken on new urgency in the wake of recent criticisms regarding IPCC's slow and inadequate responses to

reports of errors in the Fourth Assessment Report. Such criticisms underscore the need for a media-relations capacity to enable the IPCC to respond rapidly and with an appropriate tone to the criticisms and concerns that inevitably arise in such a contested arena. In addition, IPCC leaders have been criticized for making public statements that were perceived as advocating specific climate policies. Straying into advocacy can only hurt IPCC's credibility. A comprehensive communications strategy is needed to identify who should speak on IPCC's behalf and to lay out guidelines for keeping messages within the bounds of IPCC reports and mandates. IPCC's new communications and media relations manager is developing a communications strategy, and the Committee urges its rapid completion.

Recommendation: The IPCC should complete and implement a communications strategy that emphasizes transparency, rapid and thoughtful responses, and relevance to stakeholders, and which includes guidelines about who can speak on behalf of IPCC and how to represent the organization appropriately.

Transparency

Given the high stakes in the climate change debate and IPCC's role of providing policy-relevant information, the IPCC can expect that its reports will continue to be scrutinized closely. Thus, it is essential that the processes and procedures used to produce assessment reports be as transparent as possible. From extensive oral and written input gathered by the Committee, it is clear that several stages of the assessment process are poorly understood, even to many scientists and government representatives who participate in the process. Most important are the absence of criteria for selecting key participants in the assessment process and the lack of documentation for selecting what scientific and technical information is assessed. The Committee recommends that the IPCC establish criteria for selecting participants for the scoping meeting, where preliminary decisions about the scope and outline of the assessment reports are made; for selecting the IPCC Chair, the Working Group co-chairs, and other members of the Bureau; and for selecting the authors of the assessment reports. The Committee also recommends that Lead Authors document that they have considered the full range of thoughtful views, even if these views do not appear in the assessment report.

If adopted in their entirety, the measures recommended in this report would fundamentally reform IPCC's management structure while enhancing its ability to conduct an authoritative assessment. However, no matter how well constructed IPCC's assessment practices may be, the quality of the result depends on the quality of the leaders at all levels who guide the assessment process. It is only by engaging the energy and expertise of a large cadre of distinguished scholars as well as the thoughtful participation of government representatives that high standards are maintained and that truly authoritative assessments continue to be produced. Moreover, the IPCC should think more creatively about maintaining flexibility in the character and structure of the assessment, including the number and scope of Working Groups and the timing of reports. For example, releasing the assessment of regional impacts substantially after the assessment of sectoral impacts would reduce the burden on the small community that carries out both assessments. It may also be desirable to release the Working Group I report a year or two ahead

of the other Working Group reports. Although such issues are routinely raised and settled in the scoping process, the traditional approach may not be the best model for future assessments.

1
Introduction

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) to conduct assessments of the scientific basis for understanding the risk of human-induced climate change, its potential impacts, and options for adaptation and mitigation (WMO, 1988; IPCC, 1998).[1] An assessment is a process by which independent experts review and synthesize available scientific and technical knowledge relevant to climate change that is needed by policy makers to help make decisions (NRC, 2007). Thus, the IPCC assessment process sits at the interface between science and policy and necessarily involves both governments and scientists. Governments—the Member nations of WMO and UNEP—agree on the scope and outline of the periodic reports, nominate authors, review the results, and approve the Summaries for Policy Makers. They also select the scientific leaders of the assessment process. More than a thousand volunteer scientists from around the world—often supported by their universities, government laboratories, and nongovernmental organizations—evaluate the available information on climate change and draft and review the assessment reports. The task is extraordinarily complex because of the broad scope of the assessment and the fact that it is assembled by a complex, decentralized, worldwide network of scholars.

IPCC assessments have been instrumental in informing national and international climate policy options (e.g., Hulme and Mahony, 2010) as well as in raising public awareness of climate change, which earned the IPCC a share of the Nobel Peace Prize in 2007.[2] However, amidst an increasingly intense public debate over the science, impact, and cost of climate change, the IPCC has come under heightened scrutiny about its neutrality toward specific climate policies (e.g., Pielke, 2007) and the accuracy and balance of its reports (e.g., PBL, 2010). The scrutiny reached a pinnacle in early 2010 when errors, including a highly publicized mistake in the melting rate of Himalayan glaciers, were discovered in the Fourth Assessment Report. The revelation of errors came on the heels of another highly publicized controversy in which the unauthorized release of email exchanges between prominent climate scientists at the University of East Anglia and elsewhere, many of whom had contributed to IPCC assessments, purported to show attempts to misrepresent some climate data (e.g., Oxburgh et al., 2010). Although many scientists noted that neither the leaked emails nor the IPCC errors undermined the principal scientific findings regarding human contributions to climate change (Gleick et al., 2010), public opinion polls in the United States and United Kingdom showed that public confidence in climate science has waned (e.g., BBC, 2010; Jasanoff, 2010; Jowit, 2010).

In this context, Ban Ki-moon, Secretary-General of the United Nations, and Rajendra Pachauri, Chairman of the IPCC, requested the InterAcademy Council (IAC) to conduct an independent review of IPCC processes and procedures used to produce assessments (Appendix A). The Committee established by the IAC was asked to review IPCC procedures for preparing

[1] The scientific and political motivations for establishing the IPCC are discussed in Hecht and Tirpak (1995), Agrawala (1998 a, b), and Bolin (2007).
[2] See http://nobelprize.org/nobel_prizes/peace/laureates/2007/.

assessment reports, the management and administrative structure of IPCC, and IPCC strategies for communicating with the media and public, and to make recommendations for strengthening the IPCC in these areas. The specific tasks to the Committee are presented in Box 1.1.

BOX 1.1 Committee Statement of Task

The Committee will perform the following tasks:

1. Review the IPCC procedures for preparing assessment reports including, but not restricted to:
   a. Data quality assurance and data quality control;
   b. Guidelines for the types of literature appropriate for inclusion in IPCC assessments, with special attention to the use of non-peer-reviewed literature;
   c. Procedures for expert and governmental review of IPCC materials;
   d. Handling of the full range of scientific views; and
   e. Procedures for correcting errors identified after approval, adoption, and acceptance of a report.

2. Analyze the overall IPCC process, including the management and administrative functions within IPCC, and the role of UNEP and WMO, the United Nations system and other relevant stakeholders, with a view to strengthen and improve the efficiency of the assessment work and effectively ensure the consistent application of the IPCC procedures.

3. Analyze appropriate communication strategies and the interaction of IPCC with the media to ensure that the public is kept apprised of its work.

4. Prepare a report on the outcome of the activities referred to above, including:
   a. Methodology of the report preparation and measures taken to ensure high quality of the report findings;
   b. Recommendations for amendments to the IPCC procedures;
   c. Recommendations concerning strengthening the IPCC process, institutions and management functions;
   d. Any other related recommendations; and
   e. Outline of a plan for the implementation of recommendations.

This report examines the procedures and processes used to carry out IPCC assessments; it does not examine climate change science or the validity of its representation in the assessment reports. It also does not consider the work of IPCC's Task Force on National Greenhouse Gas Inventories, which is not part of the climate assessment process.

CURRENT CHALLENGES FACING THE IPCC

Carrying out an intergovernmental climate assessment is an inherently difficult task. It involves many thousands of people with different expertise, cultures, interests, and expectations. The available information on climate change is extensive, multidisciplinary, and multinational in nature; extends across multiple spatial and temporal scales; is subject to different interpretations; and has a wide range of uncertainties. In fact, a great deal remains to be discovered. The processes and procedures for carrying out the assessment must be detailed but not overly prescriptive. And while government representatives must have an important role in the assessment, they must carry out their role without asking scientists to address questions that are beyond the scientific frontier or distorting the scientific findings.

The IPCC assessment process is also complicated by several challenges that have arisen or become more acute in recent years. To begin with, the growing influence of developing nations has changed the geopolitical context for making decisions on climate change. And as the potential influence of IPCC assessments on governmental decisions that would affect the energy sector becomes increasingly clear, the IPCC finds itself in the heart of a political debate with serious economic consequences. This heated political context is amplified by a frenzied and often polarizing media environment, and communicating within this atmosphere has proven difficult.

The IPCC assessment task is further complicated by how far and how rapidly climate science has advanced in recent years. For example, the number of relevant publications that inform the drafting of an IPCC assessment grew from about 5,000 for 1991-1995 to about 19,000 for 2001-2005.[3] At the same time, the complexity of the climate system and its impacts have become increasingly apparent. The IPCC has responded to these changes by adding authors and reviewers and allowing reports to lengthen (Figure 1.1). As a result, the number of authors has tripled and the length of the reports quadrupled from the first to the fourth assessment, despite serious efforts to set page limits. In addition, the number of reviewers has more than doubled, leading to a commensurate increase in the number of review comments to be addressed. Drafts of the Fourth Assessment Report drew more than 90,000 review comments.[4] However, despite this increase in complexity, the basic management and governance structure for administering the vast undertaking of an IPCC assessment—including an intergovernmental Panel, WMO and UNEP sponsorship, three Working Groups to carry out the assessment, a small Bureau to oversee the work of the Panel, and a permanent Secretariat to provide coordination and organizational support (Agrawala, 1998b)—has not changed since the first assessment.

The sheer number of scientific disciplines involved in producing an IPCC assessment also presents a challenge given that the nature and maturity of the science varies across disciplines. Working Group I, which assesses the physical climate system, covers the natural science disciplines, including meteorology, hydrology, oceanography, ecology, and cryospheric science. The assessment relies on observations, global models, and on peer-reviewed literature, and can draw on large numbers of practitioners with a long history of collaboration. In contrast, Working Group II, which deals with impacts of climate change and strategies for adaptation, and Working Group III, which addresses mitigation options, cover dominantly social science disciplines, such as geography, economics, political science, and sociology. Working Groups II and III rely more heavily on non-peer-reviewed literature (sometimes called gray literature) and involve a smaller and more diverse set of experts who may have less experience working on large international projects. The fact that scientific expertise for all three Working Groups resides predominantly in developed countries is an ongoing challenge for dealing with a global issue.

[3] Presentation to the Committee from Rajendra Pachauri, IPCC Chair, on May 14, 2010. All review comments on the fourth assessment report are available at http://www.ipcc.ch/organization/organization_procedures.htm.
[4] Ibid.

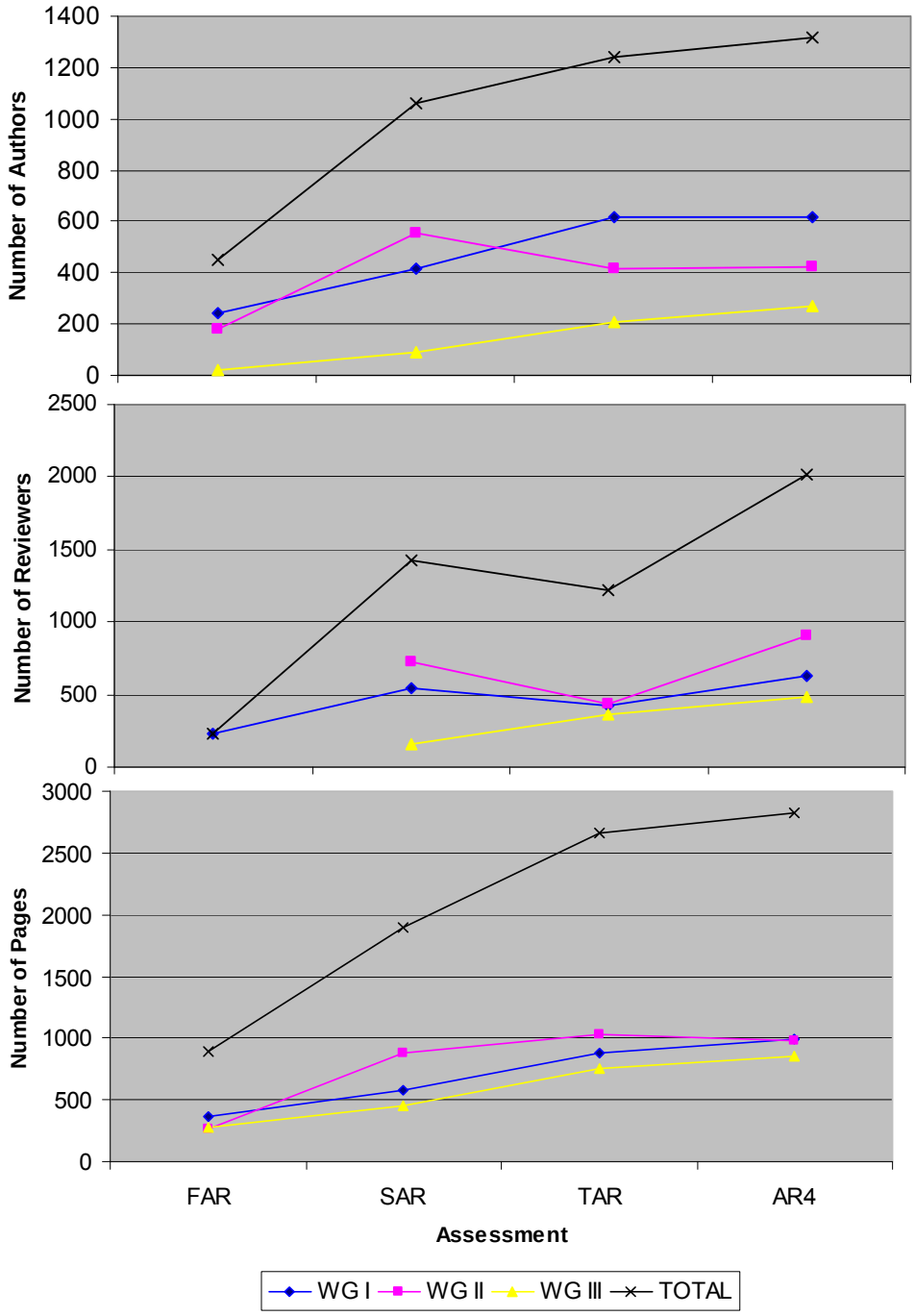

FIGURE 1.1 Trends in the number of authors (top) and reviewers (middle) and in the length of the Working Group (WG) reports (bottom) from the first assessment (FAR) to second (SAR), third (TAR) and fourth assessment (AR4). Authors who participated in two Working Groups for any given assessment are counted twice for that assessment. Reviewer names were not listed in the Working Group II or III reports for the first assessment. SOURCE: Compiled from information in the assessment reports.

COMMITTEE APPROACH AND METHODOLOGY

The IAC Committee operated independently from the UN and IPCC in conducting its review, and attempted to pursue a deliberative and consultative approach by obtaining information from a variety of sources within and outside of the IPCC, including from experts with divergent views of IPCC processes. The Committee included experts from several countries and from a variety of disciplines. Its first two meetings, held in Amsterdam and Montreal, included public, webcast sessions of presentations by IPCC and U.N. officials and by scientists with different perspectives on IPCC processes and procedures.[5] Sub-groups of the Committee also held meetings in Brazil, China, and the United States, and a sub-group visited the IPCC Secretariat in Geneva as well.

The Committee also gathered input from experts with a variety of views on the IPCC assessment process via interviews and a widely distributed questionnaire (Appendix B). The questionnaire was sent to IPCC government representatives, scientific leaders of the fourth and upcoming fifth assessments, critics and proponents of the IPCC assessment process, and organizations with an interest in the content of the assessment reports, such as scientific societies and nongovernmental organizations. The questionnaire was also posted on the Committee's website so the general public could comment. More than 400 individuals, listed in Appendix C, provided input. The prevailing views of the questionnaire respondents about the various steps in the IPCC assessment process are summarized in this report and a compilation of all of the responses, with identifiers removed, is available from the IAC.[6]

The IPCC Secretariat also supplied extensive information requested by the Committee. The Committee used this and other material to familiarize itself with IPCC's complex processes and procedures. To identify potential improvements to the assessment process, the Committee consulted published articles about the IPCC process. A growing body of literature on the characteristics of successful assessments—such as the relevance of the results to the target audience, the credibility of the analysis to the scientific community, and the legitimacy of the process to stakeholders (e.g., Cash et al., 2002; NRC, 2007)—was also taken into consideration.

A final meeting was held near London, where the Committee completed drafting its report. Following a peer review by 12 experts, the Committee finalized this report in August 2010. The IAC Board approved its publication.

OVERVIEW OF THE IPCC ASSESSMENT PROCESS

Participants

The IPCC comprises representatives of some 194 governments who meet about once a year to make major decisions about IPCC procedures, work plan, and other matters (Box 1.2). To date, three Working Groups established under the IPCC have carried out the scientific and technical assessment of climate change:

[5] Audio recordings of the presentations are available at http://reviewipcc.interacademycouncil.net/.
[6] See http://www.interacademycouncil.net/.

- Working Group I assesses the physical scientific aspects of the climate system and climate change, including attribution of past change and projections of future change.
- Working Group II assesses the vulnerability of socioeconomic and natural systems to climate change, negative and positive consequences of climate change, and options for adapting to it.
- Working Group III assesses policy and technology options for mitigating climate change through, for example, limiting or preventing greenhouse gas emissions and enhancing activities that remove them from the atmosphere.

BOX 1.2 Roles of Participants in IPCC Assessments

Panel (194 representatives of Member nations of WMO and/or UNEP)—Determines the IPCC structure, principles, procedures, work program and budget; nominates and elects the IPCC Chair and Bureau members; agrees on the scope, outline, and work plan for an assessment report; nominates authors and reviewers; approves the Summaries for Policy Makers; and accepts the reports

Government Focal Points—Coordinate IPCC activities in their country, including providing a list of national experts and compiling review comments from different government agencies

Observer organizations (80 UN bodies, intergovernmental organizations, and nongovernmental organizations)—Nominate authors and reviewers and, at the invitation of the IPCC Plenary, provide input on the scope of the assessment reports

IPCC Bureau (31 members, including the IPCC Chair, 3 IPCC Vice Chairs, 7 Working Group Co-chairs, 18 Working Group Vice Chairs, and 2 Co-chairs of the Task Force on National Greenhouse Gas Inventories (not discussed in this report)—Provide guidance and lead the author teams through preparation of an assessment report. The roles of Bureau members are not formally defined, but include the following:

- **IPCC Chair**—Plan, oversee, and guide all IPCC activities, including scoping and writing of the Synthesis Report; reporting to the governing bodies of WMO, UNEP, and the UNFCCC; and speaking for the IPCC
- **IPCC Vice Chairs**—Perform the duties of the Chair in his/her absence and other duties as mutually agreed
- **Working Group Co-chairs**—Lead the selection of authors and reviewers and the preparation, review, and finalization of their Working Group report
- **Working Group Vice Chairs**—Assist the Working Group Co-chairs, bring together regional efforts and approaches, and stimulate networking on relevant regional issues

Coordinating Lead Authors—Ensure that major sections of the report are completed and conform to style standards, and that cross-cutting scientific or technical issues are addressed in a coherent way

Lead Authors—Synthesize material for their chapter in a consistent style and revise drafts in response to reviewer comments

Contributing Authors—Provide text, graphs, or data for incorporation into the report by Lead Authors

Review Editors—Assist in identifying expert reviewers, ensure that review comments receive appropriate consideration by Lead Authors, and ensure that controversial issues are reflected adequately in the report

Expert reviewers—Comment on the scientific and technical accuracy, completeness, and balance of the draft reports

Government reviewers—Comment on the accuracy, balance, and clarity of the draft report and its consistency with the Working Group mandate

Technical Support Units (one for each Working Group, located to date near the developed-country Co-chair, each with 5-10 full-time positions)—Coordinate and administer the activities of the Working Groups, including communicating with authors and reviewers, organizing author meetings, compiling and editing drafts, and coordinating the review process, all under the supervision of the developed-country Co-chair

IPCC Secretariat—Plan, oversee, and manage IPCC activities, including organizing sessions of the IPCC Plenary and Bureau, facilitating Bureau elections, organizing travel of developing-country scientists, communicating with governments, managing the budget and website, paying expenses, and coordinating report publication and outreach

SOURCES: IPCC (1992, 1999, 2006), http://www.ipcc.ch/index.htm.

Assessment Reports

IPCC assessment reports are intended to provide a comprehensive, objective analysis of the available literature on the nature and causes of climate change, its potential environmental and socioeconomic impacts, and possible response options. The IPCC policy is to use only available scientific and technical information in the assessments. The IPCC itself does not conduct research to support the process, although expert meetings and workshops may be held in advance of an assessment to provide input on specific issues (e.g., emission scenarios),[7] and the leading modeling centers around the world contributed model output to support Working Group I in the fourth assessment.[8] The primary source of information is intended to be peer-reviewed literature. Where such literature is not available, appropriately considered and documented non-peer-reviewed literature (e.g., industry journals, workshop proceedings, reports of governments and international organizations) may be used. Although policy makers are the primary target audience, the reports are intended to be policy relevant, not policy prescriptive, and to present the range of thoughtful scientific viewpoints.

The results of the assessment are published in four volumes: three Working Group reports and a Synthesis Report. Each Working Group report includes chapters on specific topics; a Technical Summary of the chapter contents; and a Summary for Policy Makers, which highlights the key findings of the assessment. Although the scientists determine the content of the Summary for Policy Makers, the final wording is negotiated with government representatives for clarity of message and relevance to policy. The Technical Summary provides a more detailed overview of the scientific basis for those findings and also a road map to the chapters of the underlying report. The Synthesis Report is a much shorter document that integrates the findings of the three Working Group reports and summarizes the climate change issues of concern to policy makers in a non-technical style.

The IPCC Assessment Process in Brief

The IPCC assessment process begins with an evaluation of lessons learned from the previous assessment and the identification of future needs of participating governments. These are

[7] See reports of workshops and expert meetings at http://www.ipcc.ch/publications_and_data/publications_and_data_supporting_material.htm.

[8] The effort was initiated and coordinated by WMO's Working Group on Coupled Modeling. See http://cmip-pcmdi.llnl.gov/cmip3_overview.html?submenuheader=1.

discussed in one or more scoping meetings among scientists, other experts, and government representatives. The process gets underway in earnest when the Panel elects the IPCC Chair, the Co-chairs of the three Working Groups, and the rest of the Bureau. The Panel, in consultation with the newly elected Working Group Co-chairs, establishes the broad mandate of the Working Groups and the timeframe for the report (Figure 1.2). The Bureau helps develop the more detailed outline of the report and, most importantly, oversees its preparation (Box 1.2). Once governments have approved the outline and work plan for the report, the Working Group Co-chairs and Vice Chairs select the Coordinating Lead Authors and Lead Authors responsible for the scientific and technical content of their report (Box 1.2).

Coordinating Lead Authors and Lead Authors meet twice to draft the Working Group reports, enlisting text, figures, or other input from Contributing Authors as needed. The reports undergo two formal reviews and one or more informal reviews. Informal reviews of early text are provided by a small number of scientists, often other authors. The first complete draft is formally reviewed by experts with a range of views, expertise, and geographical representation nominated by governments, observer organizations, and the Bureau. The expert reviewers are asked to comment on the accuracy and completeness of the content and the overall balance of the draft (Box 1.2). The Lead Authors meet to respond to the review comments, usually in the presence of the Review Editors, and prepare the second draft. The Review Editors are responsible for ensuring that review comments and controversial issues are handled appropriately (Box 1.2). The second draft is reviewed by the same experts and by government representatives, who are asked to comment on the accuracy, clarity, and balance of the draft and its consistency with the Working Group mandate. The authors and Review Editors take into consideration the review comments in preparation of the final draft. After the report is completed, the Summary for Policy Makers is approved, line by line, in a session chaired by the Working Group Co-chairs and attended by government representatives of all Panel members. The final Working Group report is then forwarded to the Panel for acceptance.

Preparation of the Synthesis Report begins after the Working Group reports are underway. Governments determine the most important policy-relevant topics and the report outline, then a writing team—led by the IPCC Chair and including Coordinating Lead Authors of the Working Group reports and other experts—drafts the report. The draft report is reviewed by experts and governments, whose responsibilities include checking for consistency between the Synthesis Report and the Working Group reports. The Summary for Policy Makers is approved line by line, and the synthesis is approved section by section by the Panel in Plenary session.

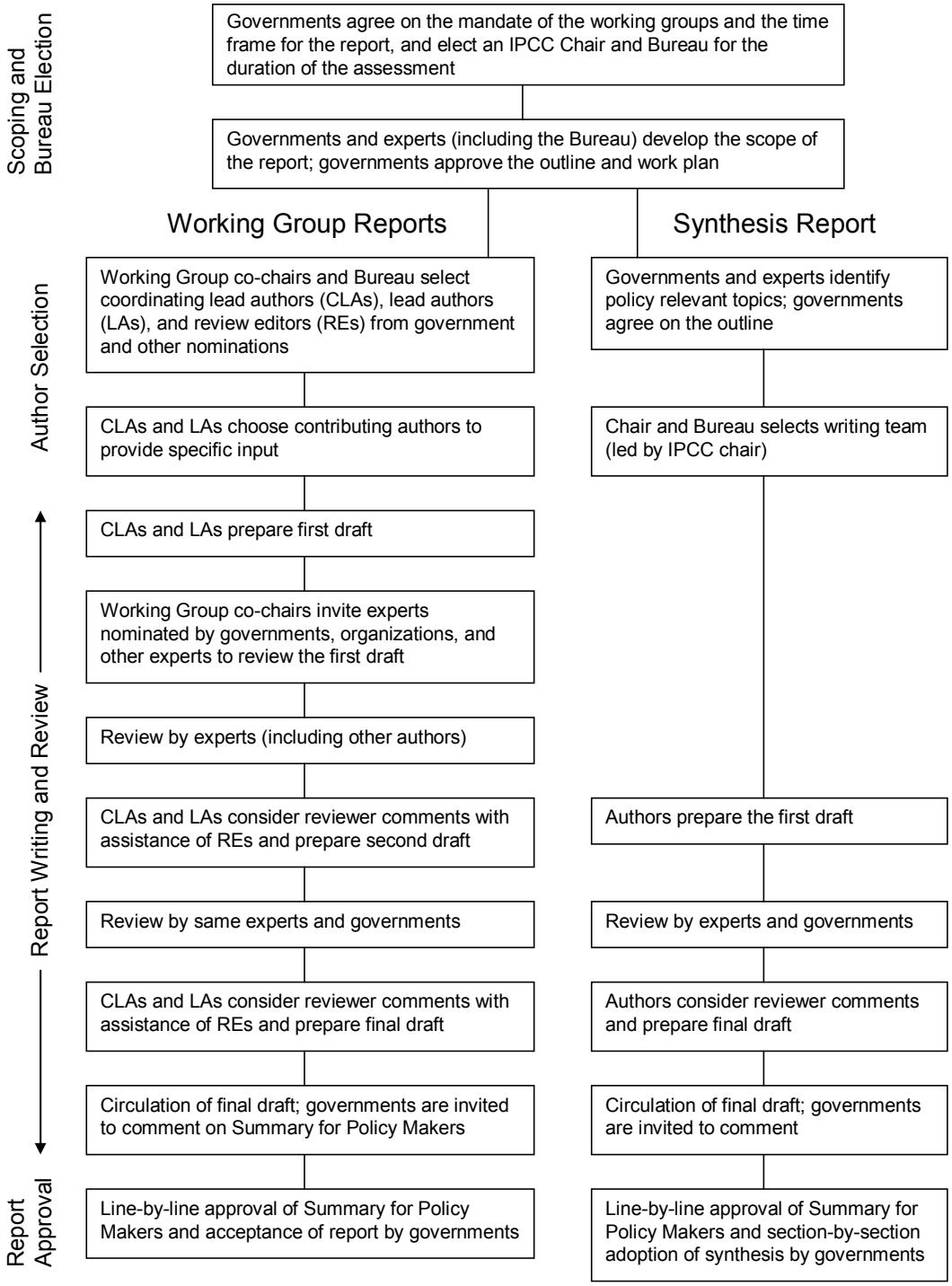

FIGURE 1.2 Process for preparing an IPCC assessment report. The initial steps (scoping and Bureau election) take place over a few years and several meetings. In this diagram, "governments" are representatives of ministries or federal agencies and "experts" are generally scientists from academia, government agencies, the private sector, and nongovernmental organizations. In general, the IPCC Secretariat facilitates the work of the Panel and supports scoping, Bureau election, government nominations, and report approval. The Technical Support Units assist the Working Group Co-chairs and support author selection and report writing and review.

ORGANIZATION OF THIS REPORT

This report on IPCC processes and procedures is intended to inform discussions at the 32nd session of the IPCC Plenary, which will be held in South Korea in October 2010, and work on the fifth assessment and subsequent assessments. For this report to be considered at the IPCC Plenary, it had to be delivered to the United Nations by August 30, 2010, for distribution to Member governments. Consequently, the Committee had only four months since its formation in late April to gather and analyze information, deliberate, and produce a peer-reviewed report. Given these time constraints, there are necessarily issues that could not be addressed in this report. Consequently, the Committee focused on the assessment process and how it is managed, and only touched on the relationship of the IPCC with WMO and UNEP.

This report reviews the IPCC assessment process and recommends ways to strengthen it. Chapter 2 evaluates the major elements of the IPCC assessment process. Excerpts of the relevant IPCC procedures are given in Appendix D. Chapter 3 examines how uncertainty was characterized and communicated in the Fourth Assessment Report and recommends ways to improve IPCC's uncertainty guidelines for subsequent assessments. Chapter 4 discusses IPCC governance, management, and communications. Chapter 5 summarizes the Committee's conclusions and identifies issues that could benefit from additional study. Appendix A provides the letters of request for an IAC review of IPCC's processes and procedures. The questionnaire seeking community input on these processes and procedures is given in Appendix B, and a list of the 400-plus individuals who contributed written or oral comments is given in Appendix C. Biographical sketches of Committee members are given in Appendix E, and a list of acronyms and abbreviations is given in Appendix F.

2
Evaluation of IPCC's Assessment Processes

An IPCC assessment is a complex process by which experts review and synthesize available scientific and technical knowledge, and governments agree on the scope of the report, nominate authors, review the results, and approve the Summary for Policy Makers (see "The IPCC Assessment Process in Brief" in Chapter 1). This chapter identifies and recommends remedies for the most significant shortcomings in each major step of IPCC's assessment process, based on the Committee's analysis of current IPCC practices, of the literature on assessments, and community input.

SCOPING

The preliminary scope and outline of IPCC assessment reports is developed by an invited group of scientists, other subject-matter experts, and government representatives. A detailed outline is then created by the Bureau and approved by the Panel. The involvement of both scientists and governments in the scoping process helps ensure that the assessment addresses issues both that can be supported by the existing scientific literature and that will be useful for supporting government decision making (NRC, 2007). IPCC's scoping process was generally supported by those who were interviewed or responded to the Committee's questionnaire (Appendix B). However, respondents raised two concerns about the scoping process. First, the scoping process itself and the selection of participants for the scoping meeting(s) remain somewhat opaque to those who have not participated. Given that the assessment process is receiving close scrutiny and that the scoping process has a major influence on the mandate and goals for the assessment, it is essential that the process be as transparent as possible.

Recommendation: The IPCC should make the process and criteria for selecting participants for scoping meetings more transparent.

The second concern relates to the outline of the assessment reports. Finalizing the outline so early in the process makes it difficult to incorporate relevant emerging scientific advances and new insights into the assessment. Moreover, governments are often interested in topics for which there is little peer-reviewed scientific and technical literature, such as the costs of adaptation. Scientists should not feel obligated to provide an assessment where no reliable information exists. Both problems would be lessened if scientists were given some flexibility to adjust the approved outlines during the assessment process without waiting for another Plenary session. Institutional arrangements that would allow greater flexibility in revising outlines after they are approved are discussed in Chapter 4 (see "IPCC Management Structure").

AUTHOR SELECTION

The selection of authors is one of the most important decisions in the assessment process because credibility of the assessment depends largely on the participation of respected scientists (e.g.,

NRC, 2007). Coordinating Lead Authors and Lead Authors are selected by the Working Group Co-chairs and Vice Chairs from a list of nominees provided by governments, observer organizations, and other experts (Appendix D). The author team for each chapter is intended to have a range of views, expertise, and geographical representation. Yet in interviews and responses to the Committee's questionnaire, some scientists expressed frustration that they have not been nominated, despite their clear scientific qualifications and demonstrated willingness to participate. Frustration was particularly strong among developing-country scientists, who felt that some of their Government Focal Points do not always nominate the best scientists from among those who volunteer, either because they do not know who these scientists are or because political considerations are given more weight than scientific qualifications. As a result, the pool of developing-country nominees may not reflect the total available capacity within these regions. Expanding the pool of well-qualified authors from all countries, for example by consulting with the Academy of Sciences for the Developing World and national science academies, learned societies, and universities, was suggested by respondents from all Working Groups, from both developed and developing countries, and from government representatives.

Although the individuals who corresponded with the Committee were generally supportive of the author teams chosen, few knew why some authors are chosen and others are not, and the selection criteria seemed arbitrary to many respondents. The absence of a transparent author-selection process or well-defined criteria for author selection can raise questions of bias and undermine the confidence of scientists and others in the credibility of the assessment (e.g., Pielke, 2010a). The IPCC has no formal process or criteria for selecting authors, although some Working Group Co-chairs established their own for the fourth assessment, considering factors such as scientific expertise and excellence, geography, gender, age, viewpoint, and the ability to work in teams.[9] Establishing such criteria and applying them in a transparent manner to all Working Groups would alleviate some of the frustrations voiced by the community.

Recommendation: The IPCC should establish a formal set of criteria and processes for selecting Coordinating Lead Authors and Lead Authors.

A concern raised by some Working Group II scientists is that the selection of the author team for each regional chapter often overlooks some of the best experts if they do not happen to live in that region. For the fourth assessment, few Coordinating Lead Authors and Lead Authors were from countries outside of the region they were assessing. Even the Contributing Authors tend to be restricted to those living in the region they assess; 5 of 7 regional chapters had no more than one outside Contributing Author. Because some of the world's foremost experts on a particular region do not live in that region, this geographic restriction sometimes limits the expertise that can be brought to bear on regional impacts. The Committee supports special efforts to find the necessary expertise within the region, but notes that having the best experts evaluate the available knowledge should be a central tenet of IPCC assessments.

Recommendation: The IPCC should make every effort to engage local experts on the author teams of the regional chapters of the Working Group II report, but should also engage experts from countries outside of the region when they can provide an essential contribution to the assessment.

[9] Written response to a Committee query by Renate Christ, IPCC Secretary, on May 7, 2010.

SOURCES OF DATA AND LITERATURE

IPCC assessments are intended to rely mainly on peer-reviewed literature. Although the peer-review process is not perfect, it ensures that the study being considered has had the benefit of independent scrutiny and quality control before it is used in the assessment. However, peer-reviewed journals may not contain all the useful information about some topics, such as vulnerabilities and adaptation and mitigation strategies of particular sectors and regions, which are a significant part of the Working Groups II and III reports. An analysis of the 14,000 references cited in the Third Assessment Report found that peer-reviewed journal articles comprised 84 percent of references in Working Group I, but only 59 percent of references in Working Group II and 36 percent of references in Working Group III (Bjurström and Polk, 2010).

In fact, information that is relevant and appropriate for inclusion in IPCC assessments often appears in the so-called "gray literature," which includes technical reports, working papers, presentations and conference proceedings, fact sheets, bulletins, statistics, observational data sets, and model output produced by government agencies, international organizations, universities, research centers, nongovernmental organizations, corporations, professional societies, and other groups. The extent to which such information has been peer reviewed varies a great deal, as does its quality.

Although some respondents to the Committee's questionnaire have recommended that only peer-reviewed literature be used in IPCC assessments, this would require the IPCC to ignore some valuable information. Examples of important, non-published or non-peer-reviewed sources include very large data sets and detailed model results (Working Group I); reports from farmer cooperatives, government agencies, nongovernmental organizations, the World Bank, and UN bodies (Working Group II); and company reports, industry journals, and information from the International Energy Agency (Working Group III). In addition, indigenous or traditional knowledge may prove useful for understanding the potential of certain adaptation strategies that are cost-effective, participatory, and sustainable (Robinson and Herbert, 2001). While such information is not always easy to find or assess, the process can be helped by the use of the worldwide web and abstracting services. The role of Lead Authors and Review Editors in the evaluation of such literature is crucial.

The current IPCC procedure requires authors to critically assess unpublished or non-peer-reviewed sources, reviewing their quality and validity before incorporating them (Appendix D). Lead Authors must also provide a copy of each source used to the Working Group Co-chairs and Secretariat staff, who are responsible for supplying copies to reviewers on request. Non-peer-reviewed sources are to be listed in the reference sections of IPCC reports, followed by a statement that they are not peer reviewed. The objectives are to ensure that all information used in IPCC reports receives some sort of critical evaluation and its use is open and transparent, and that all references used in the reports are easily accessible.

Although the Committee finds that IPCC's procedures in this respect are adequate, it is clear that these procedures are not always followed. Some of the errors discovered in the Fourth

Assessment Report had been attributed to poor handling of unpublished or non-peer-reviewed sources (Ravindranath, 2010). Moreover, a search through the Working Group reports of the fourth assessment found few instances of information flagged as unpublished or non-peer-reviewed. Clearer guidelines and stronger mechanisms for enforcing them are needed. For example, a number of respondents to the Committee's questionnaire requested clearer guidelines on the nature of acceptable unpublished or non-peer-reviewed sources. Blogs, newspaper articles, press releases, advocacy group reports, and proprietary data were thought by many to be inappropriate. Enforcement could perhaps be a job of the Review Editors, building on their role of ensuring that such literature is selected appropriately and used consistently in the report.

Recommendation: The IPCC should strengthen and enforce its procedure for the use of unpublished and non-peer-reviewed literature, including providing more specific guidance on how to evaluate such information, adding guidelines on what types of literature are unacceptable, and ensuring that unpublished and non-peer-reviewed literature is appropriately flagged in the report.

HANDLING THE FULL RANGE OF VIEWS

An assessment is intended to arrive at a judgment of a topic, such as the best estimate of changes in average global surface temperature over a specified timeframe and its impacts on the water cycle. Although all reasonable points of view should be considered, they need not be given equal weight or even described fully in an assessment report. Which alternative viewpoints warrant mention is a matter of professional judgment. Therefore, Coordinating Lead Authors and Lead Authors have considerable influence over which viewpoints will be discussed in the process. Having author teams with diverse viewpoints is the first step toward ensuring that a full range of thoughtful views are considered.

Equally important is combating confirmation bias—the tendency of authors to place too much weight on their own views relative to other views (Jonas et al., 2001). As pointed out to the Committee by a presenter[10] and some questionnaire respondents, alternative views are not always cited in a chapter if the Lead Authors do not agree with them. Getting the balance right is an ongoing struggle. However, concrete steps could also be taken. For example, chapters could include references to all papers that were considered by the authoring team and describe the authors' rationale for arriving at their conclusions.

Recommendation: Lead Authors should explicitly document that a range of scientific viewpoints has been considered, and Coordinating Lead Authors and Review Editors should satisfy themselves that due consideration was given to properly documented alternative views.

[10] Presentation to the Committee by John Christy, University of Alabama, Huntsville, on June 15, 2010.

REPORT REVIEW

IPCC's review process is elaborate, involving two formal reviews and one or more informal reviews of preliminary text. The early drafts and first complete draft are reviewed by scientific experts. These early drafts often undergo extensive revisions to reduce their length to meet page limitations established by the Bureau. After considering the review comments, the Lead Authors prepare the second draft, which is reviewed by the same experts and by government representatives. Two or more Review Editors for each chapter oversee the review process, ensuring that review comments and controversial issues are handled appropriately.

For recent assessments, some governments made the second draft available for review by national experts and other interested parties, thus considerably opening the review process. Respondents to the Committee's questionnaire generally support an open review because it increases the range of viewpoints offered and potentially improves the quality of the report, but noted the challenge of dealing with thousands of review comments (e.g., see Table 2.1). Other potential challenges created by an open review include the possibility of premature release of conclusions by the press and orchestrated efforts by those with strong views about climate change to overwhelm the system. To combat the latter, some respondents suggested requiring reviewers to provide evidence and/or appropriate citations to support their views.

Respondents also offered suggestions for making the review process less onerous, including reducing the number of formal or informal reviews, or finding a way to separate out nonsubstantive comments and undocumented opinions, thereby reducing the number of comments that Lead Authors have to deal with. A process that enables authors to focus their efforts on the most significant issues raised by reviewers has been adopted recently by the U.S. National Research Council (NRC). In this process, the individuals responsible for overseeing the review of the report (analogous to the IPCC Review Editors) prepare a written summary of the most significant issues raised by reviewers shortly after review comments have been received. Authors are asked to consider all reviewer comments, but they are required to provide written responses only to the list of most significant review issues and any other substantive reviewer comments for which they disagreed with the reviewer and did not make a change to the report. For the IPCC, it may be desirable for the authors to respond to all non-editorial comments to ensure that revisions are traceable and transparent. Removing the editorial comments from discussion would help ensure that authors and Review Editors focus their efforts on the most significant issues raised by reviewers and reduce the administrative burden of documenting responses to reviewer comments.

Recommendation: The IPCC should adopt a more targeted and effective process for responding to reviewer comments. In such a process, Review Editors would prepare a written summary of the most significant issues raised by reviewers shortly after review comments have been received. Authors would be required to provide detailed written responses to the most significant review issues identified by the Review Editors, abbreviated responses to all non-editorial comments, and no written responses to editorial comments.

TABLE 2.1 Number of Review Comments for Chapters of the Working Group II Report of the Fourth Assessment

	First Draft	Second Draft	
Chapter	**Expert Comments**	**Expert Comments**	**Government Comments**
Introduction		4	342
1. Assessment of observed changes and responses in natural and managed systems	1,563	885	319
2. New assessment methods and the characterisation of future conditions	968	412	98
3. Freshwater resources and their management	1,249	702	274
4. Ecosystems, their properties, goods and services	1,468	742	420
5. Food, fibre and forest products	1,346	541	315
6. Coastal systems and low-lying areas	1,406	420	190
7. Industry, settlement and society	863	472	247
8. Human health	1,102	606	263
9. Africa	931	627	90
10. Asia	882	526	145
11. Australia and New Zealand	1,376	543	189
12. Europe	1,078	508	244
13. Latin America	1,033	720	161
14. North America	1,329	566	142
15. Polar Regions	1,354	379	175
16. Small Islands	710	256	57
17. Assessment of adaptation practices, options, constraints and capacity	1,091	532	164
18. Inter-relationships between adaptation and mitigation	618	408	168
19. Assessing key vulnerabilities and the risk from climate change	1,065	427	274
20. Perspectives on climate change and sustainability	773	554	112
TOTAL	**22,205**	**10,826**	**4,047**

SOURCE: Data from http://ipcc-wg2.gov/publications/AR4/ar4review.html.

Even IPCC's extensive review process does not produce critical review comments on every subject covered in the reports. Such critical comments are helpful for ensuring quality and for catching errors. Targeted efforts are needed to reach additional qualified reviewers where necessary, especially on issues that support key conclusions or which are discussed in multiple chapters. In some cases, the best reviewers may be authors of different chapters or authors of other Working Group reports. Encouraging other scientific organizations, such as national science academies, to submit nominations would also increase the size of the qualified reviewer pool.

A near-universal observation—made in presentations, interviews, and responses to the questionnaire—was the need to strengthen the authority of the Review Editors to ensure that authors consider the review comments carefully and document their responses. With the tight schedule for completing revisions, authors do not always do an adequate job of revising the text and Review Editors do not always require them to explain why they rejected a comment. In the case of the incorrect projection of the disappearance of the Himalayan glaciers, for example, some of the review comments were not adequately considered and the justifications were not completely explained (see Box 2.1). Although a few such errors are likely to be missed in any

review process, stronger enforcement of existing IPCC procedures by the Review Editors could minimize their numbers. This includes paying special attention to review comments that point out contradictions, unreferenced literature, or potential errors; and ensuring that alternate or dissenting views receive proper consideration. Staff support, perhaps from the Technical Support Unit, as well as improved guidance on the roles and responsibilities of Review Editors could help Review Editors perform their duties more effectively.

Recommendation: The IPCC should encourage Review Editors to fully exercise their authority to ensure that reviewers' comments are adequately considered by the authors and that genuine controversies are adequately reflected in the report.

Although implementing these recommendations would greatly strengthen the review process, it would not make the review process truly independent because the Working Group Co-chairs, who have overall responsibility for the preparation of the reports, are also responsible for selecting Review Editors. To be independent, the selection of Review Editors would have to be made by an individual or group that is not engaged in writing the report, and Review Editors would report directly to that individual or group (NRC, 1998, 2002).

Despite the desirability of an independent review, it is not clear what scientific body has the recognized legitimacy and capacity to carry out such a large task. At the NRC, a special group called the Report Review Committee carries out this function on behalf of the institution. The Report Review Committee is made up of approximately 30 members of the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, is staffed by individuals from outside the program units, and reports directly to the NRC Governing Board. One option for the IPCC would be to appoint a small group of experts who would report directly to a new Executive Committee (see "IPCC Management Structure" in Chapter 4) to serve a similar function for the IPCC. Another option would be to engage an international scientific body to provide such services for the IPCC.

BOX 2.1 Himalaya Glaciers: Case Study on the Performance of IPCC's Report Review Process

Perhaps the most talked-about error in the fourth assessment was this statement in the Working Group II report:

> Glaciers in the Himalaya are receding faster than in any other part of the world (see Table 10.9) and, if the present rate continues, the likelihood of them disappearing by the year 2035 and perhaps sooner is very high if the Earth keeps warming at the current rate. Its total area will likely shrink from the present 500,000 to 100,000 km^2 by the year 2035 (WWF, 2005).

To determine the extent to which the error might reflect weaknesses in the IPCC review processes, the Committee examined the draft text and relevant reviewer comments. The detailed record of all the review comments and author responses maintained by the IPCC made such an analysis possible.[a] The Committee's analysis showed that 6 experts reviewed this section in the first draft and that none of their comments were critical. However, of the 12 expert reviewers' comments on the second draft (see Table 2.2), two were related to the erroneous sentence. Comment E10-466 pointed to a contradiction in the text: one sentence read "if the present rate continues, the likelihood of them [Himalayan glaciers] disappearing by the year 2035 and perhaps sooner is very high if the Earth keeps getting warmer at the present rate," and the next read "Its total area will shrink from the present 500,000 km^2 to 100,000 km^2 by the year 2035." However, the authors did not change the text.

TABLE 2.2 Reviewer Comments on the Rate of Himalayan Glacier Retreat

Comment Number	Comment	Writing Team Notes
Expert Reviewer Comments on the Second Draft		
E10-466	100,000? You just said it will disappear. (David Saltz, Desert Research Institute, Ben Gurion University)	Missed to clarify this one
E10-468	I am not sure that this is true for the very large Karakoram glaciers in the western Himalaya. Hewitt (2005) suggests from measurements that these are expanding - and this would certainly be explained by climatic change in precipitation and temperature trends seen in the Karakoram region (Fowler and Archer, J Climate in press; Archer and Fowler, 2004) You need to quote Barnett et al.'s 2005 Nature paper here - this seems very similar to what they said. (Hayley Fowler, Newcastle University)	Was unable to get hold of the suggested references will consider in the final version (sic)
E10-471	only 3 references in the last 6 pages (Clair Hanson, IPCC TSU)	More references added
E10-472	only one reference in this whole section (Clair Hanson, IPCC TSU)	More references added
Government Reviewer Comment on the Summary for Policy Makers		
GSPM-643	This is a very drastic conclusion. Should have a supporting reference otherwise should be deleted (Government of India)	Boxes removed and statements reworded and reduced to just around 8-10 lines per sector/region – see SPM FGD pages 6-10

The other reviewer (comment E10-468) questioned the statement, providing references with different conclusions. Had the authors and/or Review Editors consulted the references, they would have found two peer-reviewed articles, which, at the very least, were more cautious about the disappearance of the Himalayan Glaciers. Hewitt (2005) states:

> In the late 1990s widespread evidence of glacier expansion was found in the central Karakoram, in contrast to a worldwide decline of mountain glaciers. The expansions were almost exclusively in glacier basins from the highest parts of the range and developed quickly after decades of decline. Exceptional numbers of glacier surges were also reported.

The article by Fowler and Archer (2006) was in press at the time. The abstract states:

> The observed downward trend in summer temperature and runoff is consistent with the observed thickening and expansion of Karakoram glaciers, in contrast to widespread decay and retreat in the eastern Himalayas. This suggests that the western Himalayas are showing a different response to global warming than other parts of the globe.

In this example, IPCC's report review process failed in two ways:

1. Failure of the authors to carefully consider thoughtful review comments (E10-466 and E10-468) which would have improved the quality of the report
2. Failure of the Review Editors to ensure that reviewer comments were adequately addressed and that controversies are reflected adequately in the text of the report (E10-468)

This example also points to insufficient evaluation of non-peer-reviewed literature by the Lead Authors.

[a] See http://ipcc-wg2.gov/publications/AR4/ar4review.html.

SUMMARY FOR POLICY MAKERS

A Summary for Policy Makers is prepared for each of the three Working Group reports and for the Synthesis Report. These four summaries are arguably the most influential part of the assessment report because they are the part that policy makers are most likely to read. A team of scientists drafts the Summary for Policy Makers, and government representatives negotiate and agree to the final wording line by line. This process is intended to result in language that is understood by policy makers and to increase the chance that governments will "buy-in" to the key conclusions of the assessment.

The governments' line-by-line approval of the Summary for Policy Makers drew more concerns and suggestions for improvement by respondents to the Committee's questionnaire than any other part of the IPCC assessment process. Although most respondents agreed that government buy-in is important, many were concerned that reinterpretations of the assessment's findings, suggested in the final Plenary, might be politically motivated. However, participating governments may have diverse political agendas that may cancel each other out. Moreover, the Working Group Co-chairs and Lead Authors exercise the authority to reject proposed revisions that they believe are not consistent with their underlying Working Group report. Thus, the continued involvement of scientists in the drafting and approval process of the Summary for Policy Makers is critical to the scientific credibility of the report. A complication could arise when Lead Authors are sitting side-by-side with their government representative, which might put the Lead Authors in the difficult position of either supporting a government position at odds with the Working Group report or opposing their government's position. This may be most awkward when authors are also government employees.

Plenary sessions to approve a Summary for Policy Makers last for several days and commonly end with an all-night meeting. Thus, the individuals with the most endurance or the countries that have large delegations can end up having the most influence on the report. The process could be made somewhat more efficient by requiring all issues to be raised in advance of the Plenary, rather than allowing additional issues to be added from the floor. Another option would be to have the Panel adopt the report one section at a time (as is done for the body of the Synthesis Report) rather than approve one line at a time, and to focus on key messages. This could both speed the approval process and lessen the opportunity for political interference.

Recommendation: The IPCC should revise its process for the approval of the Summary for Policy Makers so that governments provide written comments prior to the Plenary.

Another concern of respondents to the Committee's questionnaire was the difference in content between the Summary for Policy Makers and the underlying report. The distillation of the many findings of a massive report into the relatively brief, high-level messages that characterize the Summary for Policy Makers necessarily results in the loss of important nuances and caveats that appear in the Working Group report. Moreover, the choice of messages and description of topics may be influenced in subtle ways by political considerations. Some respondents thought that the Summary for Policy Makers places more emphasis on what is known, sensational, or popular among Lead Authors than one would find in the body of the report. A recent review by the Netherlands Environmental Assessment Agency, for example, observed that the Working Group

II Summary for Policy Makers in the fourth assessment is more focused on the negative impacts of climate change than the underlying report, an approach agreed to by participating governments (PBL, 2010).

SYNTHESIS REPORT

The Synthesis Report is intended to summarize and integrate the findings of the three Working Group reports in a form designed to address issues of concern to policy makers in non-technical language. In practice, the actual framework of the Synthesis Report is negotiated within the Panel and thus varies from one assessment to the next. It is the Committee's judgment that the Synthesis Report is most valuable when it is structured as a document that attempts to integrate, not simply summarize, the findings of the three Working Group reports. This is a challenging task.

Respondents to the Committee's questionnaire were divided about the usefulness of the Synthesis Report. Scientists commonly found the report to be redundant with the Working Group reports and too political. Several thought that better integration among Working Groups would eliminate the need for a Synthesis Report. The selection of authors can be a mystery, involving an unexplained mix of Coordinating Lead Authors and Lead Authors. In contrast, government representatives generally found the report valuable and more accessible than the Summary for Policy Makers in each of the three Working Group reports. There was disagreement about whether the Synthesis Report should cover issues or policy questions, with different approaches tried in different assessments.

To date, the IPCC Secretariat has supported the production of the Synthesis Report. The Committee understands that a Technical Support Unit, based in Delhi or possibly in Geneva, will be created to assist the IPCC Chair in preparing the Synthesis Report for the fifth assessment. If this proves to be the case, the constitution and management of the Technical Support Unit will be of critical importance.

CONCLUSIONS

The overall structure of the IPCC assessment process appears to be sound, although significant improvements are both possible and necessary for the fifth assessment and beyond. Key improvements include enhancing the transparency of the process for selecting Bureau members, authors and reviewers; strengthening procedures for the use of the so-called 'gray literature'; strengthening the oversight and independence of the review process; and streamlining the report revision process and approval of the Summary for Policy Makers.

3
IPCC's Evaluation of Evidence and Treatment of Uncertainty

The evolving nature of climate science, the long timescales involved, and the difficulties of predicting human impacts on and responses to climate change mean that many of the results presented in IPCC reports have inherently uncertain components. To inform policy decisions properly, it is important for uncertainties to be characterized and communicated clearly and coherently. Beginning with the third assessment, the IPCC has issued formal guidance for characterizing and communicating uncertainty in its reports. The guidance is intended to provide a common language for expressing confidence in the conclusions and in the likelihood that a particular event will occur.

This chapter describes how each Working Group implemented the uncertainty guidance in the fourth assessment, including how uncertainty about measurements and model results are reported and how scientific confidence in report conclusions is presented in each Summary for Policy Makers and Technical Summary. This chapter also explores whether uncertainty is characterized appropriately, given the nature of IPCC assessments, and whether the scales used to characterize confidence in results are appropriate, given the nature of the conclusions. At the end of the chapter, the Committee summarizes its conclusions and recommendations for improving the presentation of evidence and treatment of uncertainty in IPCC assessment reports.

UNCERTAINTY GUIDANCE IN THE FOURTH ASSESSMENT REPORT

IPCC authors are tasked to review and synthesize available literature rather than to conduct original research. This limits the authors' abilities to formally characterize uncertainty in the assessment reports. As a result, IPCC authors must rely on their subjective assessments of the available literature to construct a best estimate and associated confidence intervals.

The IPCC guidance for characterizing uncertainty in the fourth assessment is given in Appendix D (see "Uncertainty Guidance for the IPCC Fourth Assessment Report"). The guidance describes three approaches to indicating confidence in a particular result and/or the likelihood that a particular conclusion is correct:

1. A qualitative level-of-understanding scale (Table 3.1) describes the level of scientific understanding on a particular point in terms of the amount of evidence available and the degree of agreement among experts. There can be limited, medium, or much evidence, and agreement can be low, medium, or high. According to the guidance, when the level of confidence in the scientific findings is "high agreement, much evidence," authors may use one of the quantitative scales to calibrate the level of confidence in their conclusions or the likelihood of an outcome. The guidance also allows authors to use a quantitative scale whenever they deem it appropriate.
2. A quantitative level-of-confidence scale (Table 3.2) estimates the level of confidence for a scientific finding, and ranges from "very high confidence" (9 out of 10 chance) to "very low confidence" (less than 1 out of 10 chance). The Summary for Policy Makers and the

Technical Summary use the descriptive terminology, rather than the associated numeric value.

3. A quantitative likelihood scale (Table 3.3) is used to represent "a probabilistic assessment of some well defined outcome having occurred or occurring in the future." The scale ranges from "virtually certain" (greater than 99 percent probability) to "exceptionally unlikely" (less than 1 percent probability). As in the case of Table 3.2, the Summary for Policy Makers and the Technical Summary use the descriptive terminology, rather than the associated numeric value.

TABLE 3.1 Level-of-Understanding Scale

Level of agreement or consensus →

High agreement limited evidence	...	High agreement much evidence
...	...	...
Low agreement limited evidence	...	Low agreement much evidence

Amount of evidence (theory, observations, models) →

TABLE 3.2 Confidence Scale

Terminology	Degree of Confidence in Being Correct
Very high confidence	At least 9 out of 10 chance of being correct
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

TABLE 3.3 Likelihood Scale Used by Working Group I[a]

Terminology	Likelihood of the Occurrence/Outcome
Virtually certain	> 99% probability of occurrence
Extremely likely	> 95% probability
Very likely	> 90% probability
Likely	> 66% probability
More likely than not	> 50% probability
About as likely as not	33 to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Extremely unlikely	< 5% probability
Exceptionally unlikely	< 1% probability

[a] The "extremely likely," "more likely than not," and "extremely unlikely" categories are not included in the IPCC guidance (Appendix D).

Each Working Group in the fourth assessment used the level-of-understanding, confidence, and likelihood scales in a different way. Working Group I relied primarily on the likelihood scale, but supplemented it with quantitative descriptions of uncertainty about outcomes—usually the endpoints of a 90 percent confidence interval or a probability distribution. Occasionally the

confidence scale was used in lieu of the likelihood scale. Working Group II relied primarily on the confidence scale to indicate subjective confidence in qualitative results, and occasionally on the likelihood scale (e.g., when results were quoted from Working Group I). Working Group III relied exclusively on the level-of-understanding scale.

NATURE OF EVIDENCE AND TREATMENT OF UNCERTAINTY BY EACH WORKING GROUP

The nature of the evidence presented, the extent to which the analysis is future oriented, and the characterization of uncertainty varies greatly across Working Groups. For example, much of the analysis presented by Working Group I pertains to the measurement of observable quantities, such as atmospheric carbon dioxide (CO_2) concentrations. In principle, it is possible to characterize the measurement and/or sampling error associated with these measurements using classical methods. A much smaller fraction of the literature assessed in the Working Group II and III reports pertains to measurement.

Models are used by all three Working Groups. Working Group I uses atmospheric and ocean general circulation models to model temperature in the recent past, with and without anthropogenic forcing, and to project future temperature, conditional on inputs from the Special Report on Emissions Scenarios (SRES) scenarios (IPCC, 2000). General equilibrium models of the world economy are used extensively by Working Group III to project future greenhouse gas emissions, the response of emissions to policies (e.g., a carbon tax), and the costs of reducing emissions.

Uncertainty in the model parameters can be represented using sensitivity analysis or Monte Carlo analysis. If a probability distribution can be constructed over key parameters (based on data or on expert elicitation), one could sample from the probability distribution to construct probability distributions of model outputs. Alternatively, key parameters can be varied one at a time (sensitivity analysis). Uncertainty regarding future model inputs (e.g., population, gross domestic product [GDP]) is often handled by running models conditional on common sets of inputs (scenarios). Indeed, the sets of assumptions about future population growth, growth in GDP and reliance on fossil fuels for the SRES scenarios were developed to facilitate the use of a common set of scenarios by Working Groups and researchers in the field.

A brief overview of the topics covered by each Working Group and the way uncertainty is characterized in the findings, particularly those presented in the Summary for Policy Makers, is given below.

Working Group I

The main topics covered in the Working Group I Summary for Policy Makers are: (1) changes in human and natural drivers of climate, such as greenhouse gas emissions; (2) observations of climate change in the atmosphere, cryosphere, and oceans, including sea-level rise; (3) attribution of climate change; and (4) projection of climate changes over the rest of the 21st century. The first two topics deal with measurement, either direct measurement of observable

quantities (e.g., surface temperature over the past 50 years) or indirect measurement (inferring historic CO_2 concentrations from ice cores). The last two topics use a hierarchy of models to model historic temperature or to predict temperature in the future, conditional on SRES scenarios.

Uncertainty about measured quantities is conveyed in the Summary for Policy Makers by presenting a measure of central tendency and the endpoints of a 90 percent confidence interval. The measurement uncertainty is summarized based on the authors' judgment of the confidence intervals, which are based on studies reported in detail in the chapters of the Working Group report. When models are used, uncertainties are presented as the ranges of projections generated across the different models, conditional on the SRES scenarios. Results showing uncertainty within individual models are also presented.

In addition to characterizing uncertainty using confidence intervals and probability distributions, Working Group I used a combination of the confidence and likelihood scales to characterize the certainty of their conclusions. Virtually every statement in the Summary for Policy Makers is characterized using the terms employed by one of these scales. Table 3.4 illustrates the use of the likelihood scale, including the likelihood of a trend in extreme weather events in the late 20th century, the likelihood of a human contribution to that trend, and the likelihood of future trends in the 21st century, based on the SRES scenarios.

The confidence-scale terminology is also used. For example, "There is *high confidence* that the rate of observed sea-level rise increased from the 19th to the 20th century" (IPCC, 2007a, pp. 5-7). This may be contrasted with the use of the likelihood scale to make a similar statement: ". . . losses from the ice sheets of Greenland and Antarctica have *very likely* contributed to sea level rise over 1993 to 2003" (IPCC, 2007a, p. 5).

It should be emphasized that without complementary evidence such as confidence intervals and probability distributions, the use of the phrases in Table 3.4 would be an incomplete characterization of uncertainty. In other words, the quantitative scales used by Working Group I are appropriate only because they are supplemented by quantitative measures.

TABLE 3.4 Recent Trends, Assessment of Human Influence on Trends, and Projections for Extreme Weather Events for Which There is a Late-20th Century Trend (Table SPM.2, IPCC, 2007a)

Phenomenon[a] and direction of trend	Likelihood that trend occurred in late 20th century (typically post 1960)	Likelihood of a human contribution to observed trend[b]	Likelihood of future trends based on projections for 21st century using SRES scenarios
Warmer and fewer cold days and nights over most land areas	*Very likely*[c]	*Likely*[d]	*Virtually certain*[d]
Warmer and more frequent hot days and nights over most land areas	*Very likely*[e]	*Likely (nights)*[d]	*Virtually certain*[d]
Warm spells/heat waves. Frequency increases over most land areas	*Likely*	*More likely than not*[f]	*Very likely*
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Likely*	*More likely than not*[f]	*Very likely*
Area affected by droughts increases	*Likely* in many regions since 1970s	*More likely than not*	*Likely*
Intense tropical cyclone activity increases	*Likely* in some regions since 1970	*More likely than not*[f]	*Likely*
Increased incidence of extreme high sea level (excludes tsunamis)[g]	*Likely*	*More likely than not*[f,h]	*Likely*[i]

Table notes:

[a] See Table 3.7 for further details regarding definitions.

[b] See Table TS.4, Box TS.5 and Table 9.4.

[c] Decreased frequency of cold days and nights (coldest 10%).

[d] Warming of the most extreme days and nights each year.

[e] Increased frequency of hot days and nights (hottest 10%).

[f] Magnitude of anthropogenic contributions not assessed. Attribution for these phenomena based on expert judgement rather than formal attribution studies.

[g] Extreme high sea level depends on average sea level and on regional weather systems. It is defined here as the highest 1% of hourly values of observed sea level at a station for a given reference period.

[h] Changes in observed extreme high sea level closely follow the changes in average sea level. {5.5} It is *very likely* that anthropogenic activity contributed to a rise in average sea level. {9.5}

[i] In all scenarios, the projected global average sea level at 2100 is higher than in the reference period. {10.6} The effect of changes in regional weather systems on sea level extremes has not been assessed.

The quantitative scales used by Working Group I raise four additional issues:

1. It is unclear what the use of separate confidence and likelihood scales accomplishes. For example, one could have very high confidence that obtaining two sixes when rolling a pair of fair dice is extremely unlikely. But why not just say that obtaining two sixes when rolling a pair of fair dice is extremely unlikely? This suggests that the confidence scale is redundant when the likelihood scale is used, a point also made by Risbey and Kandlikar (2007).
2. It is well documented in the literature that people interpret the terms "very unlikely," "likely" etc. in Table 3.3 in different ways (Patt and Schrag, 2003; Budescu et al., 2007; Morgan et

al., 2009). Specifically, the use of words alone is likely to lead people to underestimate the probability of high-probability events and to overestimate the probability of low-probability events (see also Lichtenstein et al., 1978).

3. The use of the likelihood scale conveys less information than a probability distribution. It should not replace ways of communicating uncertainty that convey more information when they are available. Based on a probability distribution one could say that "under scenario A1B it is very likely that mean global temperature will increase by at least 2° C by the end of the 21st century." But the distribution itself conveys this, as well as the probability of much larger mean temperature changes.
4. The likelihood scale used by Working Group I includes more categories than the likelihood scale presented in the IPCC guidance—including "extremely likely" (greater than 95 percent probability), "more likely than not" (greater than 50 percent probability), and "extremely unlikely" (less than 5 percent probability)—introducing inconsistencies in the way likelihood is presented in the Fourth Assessment Report. Moreover, the use of overlapping categories can lead to logical inconsistencies. For example, if P(A) = 0.55, then A is "more likely than not" and also "about as likely as not."

Working Group II

The Working Group II report begins with an examination of trends in various physical and biological measures (e.g., size of glaciers and lakes) that might be affected by climate change. Subsequent chapters deal with individual sectors—water; ecosystems; food, forests and fiber; coastal systems; industry, settlement, and society; and human health—and eight regions of the world. Each chapter assesses current sensitivity and vulnerability to climate, future impacts and vulnerabilities, the costs of climate change, and possibilities for adaptation. The report ends with a synthesis of impacts and implications for sustainable development.

The material assessed by Working Group II includes measurements of recent and past trends in physical and biological processes that are directly linked to climate change, such as changes in the size of glaciers and timing of plant growth. In sectors such as health and agriculture, where the link to climate is mediated by other factors, the impact of past temperature on outcomes is studied using statistical models and, in the case of agriculture, also results from experiments.

A much larger portion of the Working Group II report is devoted to projecting the future impacts of climate change. This necessarily involves projecting climate trends and future impacts, conditional on both climate change and adaptation. Both are inherently uncertain, and this uncertainty is likely to increase the farther in the future the projection is made. Different types of models are used to project future impacts. For example, projections of the impact of yield changes on world agricultural prices depend on supply and demand elasticities embedded in a model of world food markets. Consequently, model results and model uncertainty will vary, even if the same broad assumptions about future climate and adaptation are used. Best estimates from various models are often presented to show variation in the range of outcomes. Uncertainty analyses of individual models could also be presented, if available in the literature.

The extent to which results are quantified and measurement or model uncertainty is presented differs significantly across the chapters of the Working Group II report. For example, Chapter 5 (Food, Fibre, and Forest Products) presents estimates of the quantitative impacts of specific changes in temperature and precipitation on forests and agriculture, based on existing models. In contrast, Chapter 8 (Human Health) focuses on qualitative descriptions of the literature linking climate to mortality and morbidity, such as the direction of climate effects on health outcomes and the relative magnitudes of impacts.

The extent to which results are quantified also differs in the Working Group II Summary for Policy Makers and the Technical Summary. The Summary for Policy Makers presents quantitative information on the extent of agreement between different physical and biological trends and trends in temperature. Conclusions about observed impacts of climate on the natural and human environments and about future impacts (sections B and C of the Summary for Policy Makers) are usually stated in qualitative terms using the confidence and likelihood scales. No additional information is presented to characterize the uncertainty in the results of individual studies or to indicate the range of estimates across studies. In contrast, the Technical Summary includes more quantitative information about uncertainty. An illustrative figure in the Technical Summary (Figure TS.7 in IPCC, 2007b), for example, shows a range of estimates of the impact of temperature on yield changes by crop and latitude, with and without adaptation.

The Summary for Policy Makers primarily uses the confidence scale in Table 3.2, which is intended to be used when there is "high agreement, much evidence" in the literature. However, many of the conclusions in the "Current Knowledge about Future Impacts" section of the Working Group II Summary for Policy Makers are based on unpublished or non-peer-reviewed literature. For example, the following conclusions, each of which was based on a small number of unpublished studies, have been questioned (e.g., PBL, 2010):

> Towards the end of the 21st century, projected sea-level rise will affect low-lying coastal areas with large populations. The cost of adaptation could amount to at least 5-10% of GDP. (*High confidence*; IPCC, 2007b, p. 13)

> Agricultural production, including access to food, in many African countries and regions is projected to be severely compromised by climate variability and change. The area suitable for agriculture, the length of growing seasons and yield potential, particularly along the margins of semi-arid and arid areas, are expected to decrease. This would further adversely affect food security and exacerbate malnutrition in the continent. In some countries, yields from rain-fed agriculture could be reduced by up to 50% by 2020. (*High confidence*; IPCC, 2007b, p. 13)

The use of the level-of-understanding scale (Table 3.1), rather than the confidence scale (Table 3.2), would have made clear the weak evidentiary basis for these statements.

Another issue is whether it is appropriate to use quantitative subjective probabilities when statements are qualitative in nature or imprecisely stated. Many of the 71 conclusions in the "Current Knowledge about Future Impacts" section of the Working Group II Summary for Policy Makers are imprecise statements made without reference to the time period under consideration or to a climate scenario under which the conclusions would be true. Consider, for example, the statement:

> In Central and Eastern Europe, summer precipitation is projected to decrease, causing higher water stress. Health risks due to heatwaves are projected to increase. Forest productivity is expected to decline and the frequency of peatland fires to increase. (*High confidence*; IPCC, 2007b, p. 14)

There is no indication about when these events are expected to occur or under what conditions. What changes in climate would give rise to these results? What is assumed about adaptation? It could be argued that, given the imprecision of the statement, it has an 80 percent chance of being true under *some* set of circumstances.

In the Committee's view, assigning probabilities to imprecise statements is not an appropriate way to characterize uncertainty. If the confidence scale is used in this way, conclusions will likely be stated so vaguely as to make them impossible to refute, and therefore statements of "very high confidence" will have little substantive value.[11] More importantly, the use of probabilities to characterize uncertainty is most appropriate when applied to empirical quantities (Morgan et al., 2009). The following statement may be true but should not be assigned a probability of occurrence:

> Nearly all European regions are anticipated to be negatively affected by some future impacts of climate change, and these will pose challenges to many economic sectors. (*Very high confidence*; IPCC, 2007b, p. 14)

Working Group III

The main topics covered by the Working Group III Summary for Policy Makers include (1) trends in anthropogenic greenhouse emissions since 1970, (2) projected emissions to the year 2100 under various scenarios, (3) reductions in emissions in the year 2030 corresponding to various carbon prices, (4) the technical feasibility and cost of various methods of reducing greenhouse gas emissions for various sectors, and (5) estimates of the economy-wide costs of achieving various stabilization targets. There is also a discussion of the advantages and disadvantages of various policies for reducing greenhouse gas emissions, such as cap-and-trade systems and a harmonized carbon tax.

With the exception of historical trends in greenhouse gas emissions, all of the analyses by Working Group III rely on models of various sectors of the economy and are future-oriented. Top-down models are used to project global greenhouse gas emissions, their response to various policies, and the macro-economic costs of reaching various atmospheric CO_2 stabilization targets. For any geographic region, CO_2 emissions are the product of population, GDP per capita, energy usage per dollar of GDP, and the carbon intensity of energy. Policies such as a carbon tax are intended to reduce CO_2 emissions by providing incentives to lower energy per unit of GDP and to reduce the carbon intensity of energy. The response to a carbon tax depends on the costs of substituting other factors for energy and low carbon for high carbon fuels. It also depends upon how consumers respond to increases in costs.

[11] One could argue that the use of the phrase "up to" in the statement "In some countries, yields from rain-fed agriculture could be reduced by up to 50% by 2020" makes the conclusion certain to be true.

All of the factors that affect CO_2 emissions and mitigation costs in top-down models are uncertain, and uncertainty about them increases with the length of the projection. In the long run, costs of substitution depend on advances in technology, which are highly uncertain and may themselves depend on assumptions about policies. Top-down models often use scenario analysis to make statements conditional on assumptions about variables such as the rate of population growth and the rate of growth in per capita GDP (variables that are determined primarily by factors other than climate change). However, models differ in the choice of other parameters (e.g., how responsive consumers are to energy prices) and in model structure. Variation in model results was generally handled in the Fourth Assessment Report by presenting best estimates from different models or by showing a range of results across different model runs.

Working Group III also uses bottom-up models to discuss mitigation options, their cost, and policies to control them. Chapters 4-10 (IPCC, 2007c) discuss short- to medium-term options for reducing greenhouse gas emissions for seven sectors: energy supply, transport, residential and commercial buildings, industry, agriculture, forestry, and waste management. In describing the quantity of emissions that could be reduced through different options, a distinction is made between technical potential (what can be achieved by options that are technically feasible, regardless of cost); market potential (what can be achieved by options that would pay for themselves at market discount rates and various carbon prices); and economic potential (options that would be adopted using a social rate of discount and including their social benefits—for example, reductions in local pollution from switching from coal to natural gas—as well as private benefits. The chapters also discuss policies to reduce energy consumption (e.g., energy efficiency standards for buildings, fuel taxes) and their likely effectiveness in reducing emissions.

The set of bottom-up models used to estimate emissions reductions and costs by sector is more diverse than the set of top-down models, and less detail is provided about individual model results. However, ranges of estimates are generally provided about emissions reduction potentials. In Chapter 11 (Mitigation from a Cross-Sectoral Perspective) and the Summary for Policy Makers, sector-specific estimates are often aggregated to provide estimates of global mitigation potential from bottom-up studies.

The Working Group III report of the fourth assessment, including the Summary for Policy Makers and the Technical Summary, relied exclusively on the use of the level-of-understanding scale (Table 3.1), indicating the amount of evidence and level of agreement about a conclusion. Three examples of the use of this qualitative scale in the Summary for Policy Makers are given below:

> There are multiple mitigation options in the transport sector, but their effects may be countered by growth in the sector. Mitigation options are faced with many barriers, such as consumer preferences and lack of policy frameworks (*medium agreement, medium evidence*; IPCC, 2007c, p. 13)

> In 2030 macro-economic costs for multi-gas mitigation, consistent with emissions trajectories towards stabilization between 445 and 710 ppm are estimated at between a 3% decrease of global GDP and a small increase, compared with the baseline (*high agreement, medium evidence*; IPCC, 2007c, p. 11)

> Government support through financial contributions, tax credits, standard setting and market creation is important for effective technology development, innovation and deployment. Transfer of technology to developing countries depends on enabling conditions and financing (*high agreement, much evidence*; IPCC, 2007c, p. 20)

Should this scale have been supplemented with one of the quantitative scales? According to the IPCC uncertainty guidance, quantitative scales should be used when the results are themselves quantified and when there is "high agreement, much evidence." For many of the Working Group III conclusions, this is clearly not the case. Most (22 of 26) of the main conclusions in the Summary for Policy Makers are qualitative, such as the first and third statements above. The use of a likelihood scale seems inappropriate for such statements. The second statement above, which is quantitative, is based on results of a suite of models that make different assumptions about the nature of technical progress, the sensitivity of consumers and producers to changes in energy prices, and other aspects of human behavior. The Summary for Policy Makers and Technical Summary typically show the range of (best) estimates from a set of models when presenting a quantitative result. Different modeling assumptions provide a range of distinct point estimates of the quantity of interest and this range should not be interpreted as being equivalent to a prediction interval for a single, correct model. Without further attempts to distinguish among models, it would be inappropriate to apply the likelihood scale to the resulting range.

Swart et al. (2009) argue that it is inappropriate for Working Group III to use the likelihood scale because of the difficulties of modeling human choice. This is also true of Working Group II's analysis of future climate impacts and their costs, and the costs of adaptation. The uncertainty in such models is best characterized by sensitivity analyses that highlight the role of key parameters in driving model results and, when appropriate, by formal uncertainty analyses (e.g., Webster et al., 2003).

CONCLUSIONS AND RECOMMENDATIONS

The IPCC uncertainty guidance provides a good starting point for characterizing uncertainty in the assessment reports. However, the guidance was not consistently followed in the fourth assessment, leading to unnecessary errors. For example, authors reported high confidence in statements for which there is little evidence, such as the widely-quoted statement that agricultural yields in Africa might decline by up to 50 percent by 2020. Moreover, the guidance was often applied to statements that are so vague they cannot be falsified. In these cases the impression was often left, quite incorrectly, that a substantive finding was being presented.

Scientific uncertainty is best communicated by indicating the nature, number, and quality of studies on a particular topic, as well as the level of agreement among studies. The level-of-understanding scale is a convenient shorthand way of communicating this information in summary documents.

Recommendation: All Working Groups should use the qualitative level-of-understanding scale in their Summary for Policy Makers and Technical Summary, as suggested in IPCC's uncertainty guidance for the Fourth Assessment Report. This scale may be supplemented by a quantitative probability scale, if appropriate.

The IPCC uncertainty guidance urges authors to provide a traceable account of how authors determined what ratings to use to describe the level of scientific understanding (Table 3.1) and the likelihood that a particular outcome will occur (Table 3.3). However, it is unclear exactly whose judgments are reflected in the ratings that appear in the Fourth Assessment Report or how the judgments were determined. How, exactly, a consensus was reached regarding subjective probability distributions needs to be documented. The uncertainty guidance for the Third Assessment Report required authors to indicate the basis for assigning a probability to an outcome or event (Moss and Schneider, 2000), and this requirement is consistent with the guidance for the Fourth Assessment Report.

Recommendation: Chapter Lead Authors should provide a traceable account of how they arrived at their ratings for level of scientific understanding and likelihood that an outcome will occur.

In addition, IPCC's uncertainty guidance should be modified to strengthen the way in which uncertainty is addressed in upcoming assessment reports. In particular, quantitative probabilities (subjective or objective) should be assigned only to well-defined outcomes and only when there is adequate evidence in the literature and when authors have sufficient confidence in the results. Assigning probabilities to an outcome makes little sense unless researchers are confident in the underlying evidence (Risbey and Kandlikar, 2007), so use of the current likelihood scale should suffice.

Recommendation: Quantitative probabilities (as in the likelihood scale) should be used to describe the probability of well-defined outcomes only when there is sufficient evidence. Authors should indicate the basis for assigning a probability to an outcome or event (e.g., based on measurement, expert judgment, and/or model runs).

The Working Group II Summary for Policy Makers in the Fourth Assessment Report contains many vague statements of "high confidence" that are not supported sufficiently in the literature, not put into perspective, or are difficult to refute. The Committee believes that it is not appropriate to assign probabilities to such statements. There is, moreover, a danger that the confidence scale may be misinterpreted as indicating a statistical level of confidence in an outcome. Subjective probabilities may be assigned legitimately to well-defined outcomes using the likelihood scale. The presentation of results in the Fifth Assessment Report would be strengthened by assigning subjective probabilities *only* to well-defined conclusions.

Recommendation: The confidence scale should not be used to assign subjective probabilities to ill-defined outcomes.

Studies have found that individuals interpret the words in the likelihood scale very differently (Morgan et al., 2009; Patt and Schrag, 2003), even when given the terminology and probability scale in Table 3.3 (Budescu et al., 2007). An individual is more likely to understand the authors' intent if results are stated using both probability ranges and words (Budescu et al., 2007).

Recommendation: The likelihood scale should be stated in terms of probabilities (numbers) in addition to words to improve understanding of uncertainty.

Studies suggest that informal elicitation measures, especially those designed to reach consensus, lead to different assessments of probabilities than formal measures. (Protocols for conducting structured expert elicitations are described in Cooke and Goossens [2000].) Informal procedures often result in probability distributions that place less weight in the tails of the distribution than formal elicitation methods, possibly understating the uncertainty associated with a given outcome (Morgan et al., 2006; Zickfeld et al., 2007).

Recommendation: Where practical, formal expert elicitation procedures should be used to obtain subjective probabilities for key results.

4
Governance and Management

Since its founding in 1988, the IPCC has been structured in a unique way that combines its intergovernmental form with its scientific objectives. Representatives of participating governments (the Panel), in consultation with members of the Bureau, determine the scope of the assessment and review and accept the reports, and thousands of scientists from all over the world devote their professional expertise to carry out the assessment. This combination of responsibilities has both yielded a landmark sequence of global assessments related to climate change and sustained the interest and support of governments on a critical set of policy-relevant climate issues.

Although many of IPCC's processes and procedures for carrying out assessments have evolved over the years, its fundamental management structure has remained largely unchanged. In that time, the complexity and scale of the subject matter, the associated assessment processes, and the variety of interested stakeholders have grown significantly (see "Current Challenges Facing the IPCC" in Chapter 1). Moreover, the IPCC assessment process has come under ever-increasing pressures from a wide variety of stakeholders who are hoping for evidence that their interests are supported by the latest developments on the scientific frontier. This is not a surprising development in an arena where so much is at stake, where so many interests collide, and where many uncertainties remain.

At the same time, charitable and educational trustee bodies, government organizations, and private corporations have been undergoing what may be described as a governance revolution, in which management and governance structures are now expected to be more accountable to a wider range of interests.[12] Although the IPCC is a different kind of organization, it faces even more acute issues of accountability and transparency, given the broad public policy interests associated with climate change. However, these new expectations are not yet reflected in the current governance and management structure of the IPCC.

This chapter evaluates IPCC's current management structure and approach to communications as well as governance issues, such as conflict of interest and disclosure. The Committee's analysis was informed by a visit to the IPCC Secretariat in Geneva and a 2009 report of an IPCC Task Group, which examined the IPCC Secretariat (IPCC, 2009).

IPCC MANAGEMENT STRUCTURE

As described in Chapter 1, management of the IPCC assessment process is distributed among four entities:

[12] For example, the HMG Companies Act of 2009 introduced sweeping new requirements (e.g., disclosure and conflict of interest) on all listed companies in the private sector in the United Kingdom.

1. The Panel meets annually to make decisions about the structure, principles, procedures and work program of the IPCC. In some years, it also determines the broad scope of the assessment, elects a Bureau to oversee the work, or reviews and approves the Summary for Policy Makers, depending on the stage of the assessment.
2. The IPCC Chair plans, oversees, and guides all IPCC activities, including chairing the Plenary sessions of the Panel, overseeing the Secretariat on scientific and technical matters, leading the scoping and writing of the Synthesis Report, and speaking on behalf of the IPCC.
3. The Bureau, especially the individual Working Group Co-chairs and Vice Chairs, is responsible for the detailed planning and execution of the assessments, including the selection of authors and expert reviewers.
4. The IPCC Secretariat facilitates the work of the Panel and Bureau and the participation of developing country scientists, manages the budget and website, and coordinates report production and outreach.

The Panel

The IPCC has reporting responsibilities to four United Nations bodies: UNEP, WMO, the United Nations Framework Convention on Climate Change (UNFCCC), and the UN General Assembly. Legally, the IPCC is an intergovernmental joint subsidiary panel of WMO and UNEP, but it has operated in practice as if it were an independent organization. Perhaps as a consequence, although strongly supportive of the IPCC, WMO and UNEP officials appear to exert modest oversight over the organization.[13] This relationship bears further investigation, as does IPCC's relationship to the UNFCCC.

The IPCC makes all of its major decisions at annual Plenary sessions. Although the Panel's elected subsidiary—the IPCC Bureau—can act on some issues between sessions, there are no effective formal mechanisms for the Panel to carry out key responsibilities at all times. IPCC's difficulty in responding to recent controversies, such as the errors in the Fourth Assessment Report, illustrates that such a mechanism is sorely needed. To help fill this decision-making gap, the IPCC established an ad hoc Executive Team—comprising the IPCC Chair, Vice Chairs, Working Group Co-chairs, Secretary, and the heads of the Technical Support Units—to meet monthly, usually electronically. However, the Executive Team lacks authority and its decisions are sometimes ignored or overturned (IPCC, 2009). A more powerful group is needed to look after the interests of the organization and to respond to issues as they arise.

Recommendation: The IPCC should establish an Executive Committee to act on its behalf between Plenary sessions. The membership of the Committee should include the IPCC Chair, the Working Group Co-chairs, the senior member of the Secretariat, and 3 independent members, including some from outside of the climate community. Members would be elected by the Plenary and serve until their successors are in place.

[13] Presentations to the Committee by Achim Steiner, Executive Director of UNEP, on May 14, 2010, and Michel Jarraud, Secretary General of WMO, on June 15, 2010.

The Executive Committee would have the authority to act on the following issues:

- Approving modest alterations to the scope of an ongoing assessment in response to new scientific developments
- Approving minor corrections to published reports
- Ensuring effective ongoing communication with stakeholders, especially the media, including responding to errors
- Addressing cross-cutting issues, such as ensuring, where appropriate, communication and cooperation among Working Groups
- Other tasks as specifically delegated by the Panel.

The Executive Committee would be elected by and report to the Panel, and chaired by the IPCC Chair. To be nimble, the Executive Committee would best be limited to ideally no more than 12 individuals. Most members of the Executive Committee would be drawn from the Bureau and thus would be knowledgeable about the assessment process. However, having a viable group of truly independent members with relevant experience and qualifications would improve the credibility and independence of the Executive Committee. These individuals should be widely respected in their fields and should be drawn from academia, nongovernmental organizations outside of the UN system, and/or the private sector. To ensure that a substantial pool of well-qualified individuals is identified for the Executive Committee, the IPCC should consult a broader group of organizations beyond those that currently submit nominations for the Bureau and other positions.

The IPCC Chair

In line with UN practice for panels and working groups, member countries elect the IPCC Chair for a fixed term, in this case for the period of an assessment. IPCC procedures limit the Chair to two terms. The Chair receives no salary from the IPCC, but is supported by his or her home nation and/or institution. Although a significant proportion of their time has been devoted to their chairmanship role, each of the three Chair incumbents to date has had significant professional responsibilities outside of the IPCC.

The fixed term and part-time nature of the chairmanship continues to hold many advantages. A fixed term is important because over time it allows for a greater variety of perspectives and approaches to the assessment, and turnover in leadership is one key to maintaining the ongoing vitality of assessments. A 12-year appointment (two terms) is too long for a field as dynamic and contested as climate change. Because the IPCC Chair is both the leader and the face of the organization, he or she must have strong credentials (including high professional standing in an area covered by IPCC assessments), international stature, a broad vision, strong leadership skills, considerable management experience at a senior level, and experience relevant to the assessment task.

Recommendation: The term of the IPCC Chair should be limited to the timeframe of one assessment.

The IPCC Bureau

The IPCC Bureau comprises the IPCC Chair, IPCC Vice Chairs, and the Working Group Co-chairs and Vice Chairs, as well as the Co-chairs of the Task Force Bureau on National Greenhouse Gas Inventories (Figure 4.1). The overall composition of the IPCC Bureau is intended to ensure balanced geographic representation with due consideration for scientific and technical requirements (IPCC, 2006). The current regional balance prescribed in the IPCC procedures is 5 members from Africa; 5 members from Asia; 4 members from South America; 4 members from North America, Central America, and the Caribbean; 3 members from the southwest Pacific; and 8 members from Europe. The IPCC Chair does not represent a region. Government representatives nominate Bureau members, and voting is by secret ballot. Like many elections, intense negotiations are carried out in advance of the formal vote. Members of the Bureau are eligible to serve for 2 consecutive terms.

Two Co-chairs are elected for each Working Group: one from a developed country and one from a developing country. Each pair of Working Group Co-chairs is supported by a Technical Support Unit which is funded by the country of one of the Co-chairs. The cost of supporting the Technical Support Unit, which is staffed by the equivalent of about 5-10 full-time people, effectively limits the Co-chair nominations pool to those countries willing to provide this financial support. To date, only developed countries have been willing to bear this cost. In practice, this has meant that any developed country that nominates a Co-chair for a Working Group has to be willing to fund a Technical Support Unit.[14] One way to overcome this limitation is to encourage foundations or private corporations to help developing countries establish a Technical Support Unit, provided that such contributions are made without any precondition by the donor(s).

The Technical Support Units are generally headed by scientists or science managers and include both scientific and administrative staff who are responsible for coordinating and administering the activities of their Working Group. Their tasks include communicating with authors and reviewers, organizing author meetings, compiling and editing drafts, and coordinating the review process, all under the supervision of the Working Group Co-chair whose country provides the financial support. As a result, the Co-chair of the Working Group whose country supports and houses the Technical Support Unit generally has a particularly strong voice in the Working Group.

The Working Group Co-chairs have significant influence and control over the assessment, leading the preparation, review, and finalization of their Working Group report. The importance of the Working Group Co-chairs makes it essential that they have the highest scientific and leadership credentials. The IPCC has not established formal qualifications for Working Group Co-chairs, although, as many respondents to the Committee's questionnaire point out, somehow the current process has generally resulted in the election of appropriately talented individuals. Nevertheless, formal criteria could help ensure that well-qualified individuals are nominated.

Recommendation: The IPCC should develop and adopt formal qualifications and formally articulate the roles and responsibilities for all Bureau members, including the IPCC Chair,

[14] Written response to a Committee query by Renate Christ, IPCC Secretary, on May 7, 2010.

to ensure that they have both the highest scholarly qualifications and proven leadership skills.

The task of the Working Group Co-chairs is both intellectually demanding and time consuming. Perhaps as a consequence, most Working Group Chairs to date have served only one term. Nevertheless, the arguments for encouraging turnover among the IPCC leadership apply also to the Working Group Co-chairs, given their great influence on the assessment.

Recommendation: The terms of the Working Group Co-chairs should be limited to the timeframe of one assessment.

Chair
Rajendra K. Pachauri

IPCC Vice Chairs		
Ismail A.R. El Gizouli (Sudan - Acting Vice - Chair)	Jean-Pascal van Ypersele (Belgium)	Hoesung Lee (Republic of Korea)

Working Group I The physical science basis	Working Group II Impacts, adaptation, vulnerability	Working Group III Mitigation of Climate Change	Task Force Bureau National Greenhouse Gas Inventories
Co-chairs	**Co-chairs**	**Co-chairs**	**Co-chairs**
Thomas Stocker (Switzerland)	Christopher Field (USA)	Ottmar Edenhofer (Germany)	Taka Hiraishi (Japan)
Dahe Qin (China)	Vicente Barros (Argentina)	Ramon Pichs-Madruga (Cuba)	Thelma Krug (Brazil)
		Youba Sokona (Mali)	
Vice Chairs	**Vice Chairs**	**Vice Chairs**	
Abdalah Mokssit (Morocco)	Nirivololona Raholijao (Madagascar)	Ismail A.R. El Gizouli (Sudan)	
Fatemeh Rahimzadeh (Islamic Republic of Iran)	Amjad Abdulla (Maldives)	Suzana Kahn Ribeiro (Brazil)	
Francis Zwiers (Canada)	Eduardo Calvo Buendia (Peru)	Antonina Ivanova Boncheva (Mexico)	
Fredolin T. Tangang (Malaysia)	Neville Smith (Australia)	Carlo Carraro (Italy)	
David Wratt (New Zealand)	Jose M. Moreno (Spain)	Jim Skea (UK)	
Jean Jouzel (France)	Sergey Semenov (Russian Federation)	Taha Zatari (Saudi Arabia)	

FIGURE 4.1 Organization and membership of the IPCC Bureau for the fifth assessment. The Task Force Bureau on National Greenhouse Gas Inventories is not involved in the assessment process.

The Secretariat

The Secretariat is the only operational unit of the IPCC that remains active between assessment reports, and thus provides important institutional continuity and centralized administrative support. It comprises 10 individuals, including the Secretary; a Deputy Secretary (currently a WMO retiree); a science officer; a communications specialist; an information technology officer; a financial administrator; and office assistants who handle travel, meetings, and outreach. There are also part-time staff and consultants who are not formally posted to the Secretariat. The Secretariat reports to the IPCC Chair on technical issues and most administrative matters, and to UNEP and WMO on personnel issues. It is housed in the WMO building in Geneva.

Respondents' views on the effectiveness of the Secretariat are mixed, as are the suggested possible solutions. Some respondents to the Committee's questionnaire, for example, found the Secretariat to be political and ineffective and recommended a more professional management structure. Others thought that it does a fine job, but that the structure is too lean given the increased responsibilities that have come with a larger, more complex assessment. Many respondents cautioned against simply expanding the Secretariat, recommending instead more strategic enhancements. A similar diversity of views has been expressed by Member governments (IPCC, 2009).

The 2009 IPCC Task Group recommended that the Secretariat's focus remain on organizational and administrative matters, with a secondary focus on supporting the scientific and technical activities of the IPCC. The Committee agrees, but notes that advances in digital technologies (see "Access to Information" in Chapter 5) and new communications needs (see "Communications" below) have changed the mix of skills needed at the Secretariat and possibly the number of staff needed. The extensive and diverse responsibilities of the Secretariat can no longer be discharged satisfactorily with the current combination of scale, job assignments, and the restrictions on staffing and budget imposed by its position in the context of a UN specialized agency.

Recommendation: The IPCC should redefine the responsibilities of key Secretariat positions both to improve efficiency and to allow for any future senior appointments.

Although the Committee could not specify all of the roles and responsibilities of all staff in the Secretariat, it is clear that a new architecture is needed. In particular, a new position of Executive Director is necessary to lead the Secretariat, ensure that IPCC protocols for processes and timelines are followed, and keep in touch with the Working Groups. A nominations committee established by the proposed Executive Committee would develop a slate of candidates, and the Executive Director would be elected by the Panel in Plenary session. The Executive Director would serve as an ex officio member of the Executive Committee. Consequently, the Executive Director should be a peer of the Working Group Co-chairs. In addition, he or she should have a reputation for integrity and independence and should be a good networker; be familiar with the interface between science and public policy; and be capable of speaking, and authorized to speak, on behalf of the IPCC. To attract the best scientists and add vitality to the organization, the position would have a term of only 5 to 7 years (a full assessment period), and would continue until the Working Group Co-chairs for the subsequent assessment are elected.

A full-time Executive Director is often found alongside a part-time Chair in other organizations (e.g., FRC, 2010). Such a senior individual has the full confidence of the Chair and can act on his or her behalf as needed. The only senior-level management position in the current IPCC structure is the IPCC Secretary. Although at a high (D2) director grade, the Secretary does not carry either the equivalent level of autonomy or responsibility as Executive Directors of other international organizations.

Recommendation: The IPCC should elect an Executive Director to lead the Secretariat and handle day-to-day operations of the organization. The term of this senior scientist should be limited to the timeframe of one assessment.

CONFLICT OF INTEREST AND DISCLOSURE

A key governance feature of institutions that deal with broad public policy interests is the consideration of conflict of interest (NRC, 2002). The term "conflict of interest" refers to any financial or other interest that compromises the service of an individual by significantly impairing the individual's objectivity or creating an unfair competitive advantage for any person or organization. Conflict of interest means something more than a strong view or bias—there must be an interest, ordinarily financial, that could be directly affected by the individual's participation (NAS, 2003).

Many governmental and nongovernmental institutions that carry out scientific assessments or provide scientific advice have adopted conflict of interest and disclosure policies in order to assure the integrity of, and public confidence in, their results (BPC, 2009). For example, the nongovernmental U.S. National Research Council, which carries out hundreds of scientific assessments every year, has a well-established and well-documented policy on conflict of interest and disclosure (NAS, 2003).

Some international institutions that carry out scientific assessments, such as the WMO and UNEP, have adopted codes of conduct that address conflict of interest issues for their staff. For example, WMO's code of ethics requires staff to avoid any conflict of interest, or appearance of conflict of interest, in the performance of their duties by: (1) disclosing in advance possible conflicts of interest that might arise; (2) refraining from acting on any matter in which they, someone with whom they have a close relationship, or someone from whom they are seeking a benefit or favor, has a special interest; and (3) refraining from associating with the management holding financial interest in any profit seeking or other concern which might benefit by reason of their position in the WMO.[15] The latter also holds true for UNEP, and all staff members at the assistant secretary level and above are required to file confidential financial disclosure statements at regular intervals (UN, 2003). WMO and UNEP have not established conflict of interest or disclosure policies for experts who serve on most WMO and UNEP assessment teams. The UNEP Secretariat responsible for recent ozone assessments established a code of conduct for some of its panels that requires its members "to avoid conflicts of interests in the performance of their duties," but panel members are not required to fill out disclosure forms (UNEP, 2006). Other scientific assessments, such as the Millennium Ecosystem Assessment and the Global

[15] See http://www.wmo.int/pages/governance/ethics/Code%20of%20Ethics%20%28E%29.pdf.

Biodiversity Assessment, have neither conflict of interest nor disclosure policies for their authors.

The IPCC does not have a conflict of interest or disclosure policy for its senior leadership (i.e., IPCC Chair and Vice Chairs), Working Group Co-chairs and authors, or the staff of the Technical Support Units. The professional staff members of the IPCC Secretariat are employees of WMO and/or UNEP and are subject to their disclosure and ethics policies. In particular, all IPCC Secretariat staff in Geneva, except for the Deputy Secretary, are WMO employees and therefore are required to follow the WMO code of ethics; the IPCC Deputy Secretary follows UN staff regulations; and the IPCC Secretary must comply with the rules for both UN and WMO staff because the Secretary is seconded from UNEP and WMO.

The lack of a conflict of interest and disclosure policy for IPCC leaders and Lead Authors was a concern raised by a number of individuals who were interviewed by the Committee or provided written input. Questions about potential conflicts of interest, for example, have been raised about the IPCC Chair's service as an advisor to, and board member of, for-profit energy companies (Booker and North, 2009; Pielke, 2010b), and about the practice of scientists responsible for writing IPCC assessments reviewing their own work. The Committee did not investigate the basis of these claims, which is beyond the mandate of this review. However, the Committee believes that the nature of the IPCC's task (i.e., in presenting a series of expert judgments on issues of great societal relevance) demands that the IPCC pay special attention to issues of independence and bias to maintain the integrity of, and public confidence in, its results.

The IPCC Secretariat informed the Committee that the Panel will be discussing options for conflict-of-interest and disclosure policies for the various actors in the IPCC process (e.g., members of the Bureau, non-UN staff, non-WMO staff, and authors) at its next Plenary session.

Recommendation: The IPCC should develop and adopt a rigorous conflict of interest policy that applies to all individuals directly involved in the preparation of IPCC reports, including senior IPCC leadership (IPCC Chair and Vice Chairs), authors with responsibilities for report content (i.e., Working Group Co-chairs, Coordinating Lead Authors, and Lead Authors), Review Editors, and technical staff directly involved in report preparation (e.g., staff of Technical Support Units and the IPCC Secretariat).

In developing such a policy, the IPCC may want to consider features of the NRC policy. These include:

- Distinguishing between strong points of view (i.e., biases) that can be balanced and conflicts of interest that should be avoided unless determined to be unavoidable
- Differentiating between current conflicts, where the candidate's current interests could be directly and predictably affected by the outcome of the report, and potential conflicts of interests
- Considering a range of relevant financial interests, such as employment and consulting relationships; ownership of stocks, bonds, and other investments; fiduciary responsibilities; patents and copyrights; commercial business ownership and investment interests; honoraria; and research funding

- Judging the extent to which an author or Review Editor would be reviewing his or her own work, or that of his or her immediate employer
- Examining indications of a fixed position on a particular issue revealed through public statements (e.g., testimony, speeches, interviews), publications (e.g., articles, books), or personal or professional activities
- Maintaining up-to-date confidential disclosure forms and participating in regular, confidential discussions of conflict of interest and balance for the major components of each report.

The policy should strike the appropriate balance between the need to minimize the burden on IPCC volunteers and the need to ensure the credibility of the process. To implement the policy, the IPCC will have to designate a senior individual, such as the proposed Executive Director, to review the disclosure forms, lead discussions of conflict of interest and balance, and make decisions about potential conflicts of interests.

COMMUNICATIONS

Scientists have long struggled to effectively communicate their findings to wider audiences. Communicating the complex science of climate change, including the degree of consensus among scientists and areas of uncertainty, is particularly challenging. Many respondents to the Committee's questionnaire found communication to be a major weakness of the IPCC. Their primary concerns were IPCC's slow and inadequate responses to reports of errors and public statements by IPCC leaders that could be perceived as policy advocacy. This age of instant communication offers new opportunities for disseminating the findings of climate scientists, but it also makes doing so more challenging given how audiences are bombarded by so many competing, and often polarizing, sources of information.

The communications challenge for the IPCC is exemplified by its response to the discovery of an error in the Fourth Assessment Report regarding the melting rate of Himalayan glaciers. IPCC's official statement on the matter—issued more than a month after the error was widely publicized—did not state whether an error, in fact, had occurred or whether an erratum would be issued.[16] The IPCC leadership attributed this sluggish response to a lack of communications capacity at the Secretariat (the lead communications position was vacant at the time) and a breakdown in the relationship between the Secretariat and the disbanded Working Groups and Technical Support Units of the fourth assessment. The IPCC responded more quickly to claims of other errors in the Fourth Assessment Report, either explaining why it believed news reports were wrong or acknowledging a mistake (Leake, 2010; Reuters, 2010).[17]

Improving communications and outreach is discussed regularly at IPCC sessions. An IPCC Outreach Task Group recommended hiring a communications expert in 2003 (IPCC, 2003). One was appointed to the IPCC Secretariat in 2006. In 2005, the IPCC commissioned a consulting firm (CNC) to develop a communications strategy for the release and dissemination of the Fourth Assessment Report (IPCC, 2005a). The CNC communications strategy also contains

[16] See http://www.ipcc.ch/pdf/presentations/himalaya-statement-20january2010.pdf.
[17] See IPCC erratum at http://www.ipcc.ch/publications_and_data/ar4/wg2/en/erratataserrata-errata.html.

recommendations that are pertinent to current challenges, including a process for devising responses to media comments with the appropriate tone and language, giving several people authority to speak on IPCC's behalf, and guidelines for keeping messages within the bounds of IPCC reports and mandates.

IPCC's mandate is to be policy relevant, not policy prescriptive. However, as noted above, IPCC spokespersons have not always adhered to this mandate. Straying into advocacy can only hurt IPCC's credibility. Likewise, while IPCC leaders are expected to speak publicly about the assessment reports, they should be careful in this context to avoid personal opinions. The opinion of an IPCC representative can be interpreted as the official IPCC position, regardless of how the representative voices his or her views.

The IPCC Chair is the most visible public face and most often-quoted representative of the IPCC. Relying so heavily on a sole spokesperson carries the risk that audiences will not appreciate the collaborative process involved in developing IPCC positions. A sole spokesperson is also less likely to be available to provide timely responses to media inquiries.

The IPCC's primary means for communicating to audiences outside of the scientific community are the Summaries for Policymakers and the Synthesis Report. However, it is not clear how useful these documents are on their own. The Working Group I report in the fourth assessment also included a user-friendly Frequently Asked Questions (FAQ) section, written by Lead Authors and taken directly from the chapters of the underlying report. However, the IPCC thus far has chosen to leave the production of materials for lay audiences (derivative material) to partner organizations. There are no press releases accompanying the assessment reports. As part of its effort to finalize the Summary for Policy Makers, the IPCC may want to consider approving press release text to help journalists better understand and report on the assessment reports.

The IPCC Secretariat and Working Groups organized dozens of outreach events in developed and developing countries following release of the Fourth Assessment Report. These events targeted a variety of individuals and groups, including heads of state, chief executives of private companies, journalists, nongovernmental organizations, academic societies, civic organizations, students, legislators, cabinet ministers, and others.[18] Having derivative material written for and relevant to these stakeholders would likely facilitate these outreach efforts. Moreover, such sessions would be most effective if scientists engage audiences in a two-way conversation rather simply explaining their findings (Nisbet and Scheufele, 2009). Framing the discussion to take into account an audience's cultural values also can be beneficial (Kahan, 2010).

The IPCC participates in a Task Force on Climate Change within the UN Communications Group, in which UN information officers working on climate change issues share ideas and discuss opportunities to work together. Communication strategies employed by other scientific organizations could also help inform IPCC communication practices. These include rapid and broad dissemination of news and press releases through online social media, the institution's website, and clearinghouses for research news (e.g., EurekAlert, AlphaGalileo); ready access of

[18] See IPCC progress reports on outreach at http://www.ipcc.ch/pdf/session27/doc7.pdf and http://www.ipcc.ch/meetings/session29/doc7.pdf for listings of events.

media experts to institution leaders so responses to crises can be developed rapidly; and media training for spokespersons. Communicators at science organizations also help maintain transparency by explaining their institution's policies and procedures. In addition, trained science writers can translate technical language into text suitable for mass communication or design websites that explain scientific concepts to lay audiences while staying true to the underlying evidence.

The recently appointed IPCC communication and media relations manager has held media training sessions for some IPCC experts and drafted a communications strategy for consideration by the Panel in October 2010. Working Group II for the Fifth Assessment Report has also retained a communications consulting firm[19]to support it as well as the Secretariat.

Recommendation: The IPCC should complete and implement a communications strategy that emphasizes transparency, rapid and thoughtful responses, and relevance to stakeholders, and which includes guidelines about who can speak on behalf of IPCC and how to represent the organization appropriately.

Possible elements of an IPCC communications strategy include:

- More user-friendly derivative products based on assessment reports, such as a booklet that answers questions asked frequently by policy makers, individuals skeptical about climate change, and the interested public. Given how carefully the language in the assessment reports is crafted and approved, the text of derivative products should be approved by the Working Group Co-chairs or other key authors to ensure the language is consistent with the underlying assessment. Because the Working Groups disband after release of their reports, any derivative products may need to be created as the assessments reach approval or shortly thereafter.
- A FAQ section in each Working Group report
- A rapid response plan to reply, in a coordinated and timely manner and with an appropriate tone, to the criticisms and concerns that inevitably arise in such a contested arena
- Empowerment of and training for appropriate IPCC leaders to speak to the media not only about the content of the assessment reports but also the process used to generate them

Additional human and financial resources may be needed for the IPCC to perform the communication functions required of an organization with the public stature of the IPCC. In particular, the IPCC needs a senior communications officer or press secretary with established credibility, standing, and expertise to carry out this role.

CONCLUSIONS

IPCC's management and governance structure is not as effective as necessary to manage a larger and more complex assessment and to respond to a larger and more demanding group of stakeholders. The modified structure proposed for the IPCC by the Committee retains the

[19] A June 23, 2010, press release from Working Group II lists a media contact from Resource-Media, a U.S. based non-profit communication group. See http://www.ipcc-wg2.gov/WGII_Press_release6-23-10.pdf.

decentralized structure, which is a key to IPCC's continued vitality and authority, but adds flexibility and strength to its administrative support function.

Because the individuals involved in the IPCC assessment process carry the burden and responsibility of maintaining the public's trust, it is important for all involved to act with transparency and integrity and to abide by appropriate codes of conduct. Public trust in science also depends on effective communication, and there are many opportunities to enhance the usefulness of IPCC assessments as tools for informing policymaking and public discourse.

5
Conclusions

IPCC'S PROCESSES AND PROCEDURES

The Committee concludes that the IPCC assessment process has been successful overall and has served society well. The commitment of many thousands of the world's leading scientists and other experts to the assessment process and to the communication of the nature of our understanding of the changing climate, its impacts, and possible adaptation and mitigation strategies is a considerable achievement in its own right. Similarly, the sustained commitment of governments to the process and their buy-in to the results is a mark of a successful assessment. Through its unique partnership between scientists and governments, the IPCC has heightened public awareness of climate change, raised the level of scientific debate, and influenced the science agendas of many nations. However, despite these successes, some fundamental changes to the process and the management structure are essential, as discussed in this report and summarized below.

Summary of Recommendations

Modernizing the management structure. Since its inception more than two decades ago, the governance and basic elements of the management structure of the IPCC have changed very little. Meanwhile, the magnitude and complexity of the assessment task has increased and new demands are being made for increased transparency and accountability. Best practices in other organizations provide a model for the IPCC to renew its governance and management structure. Key elements of this structure include the establishment of an Executive Committee to act on behalf of the Panel between Plenary sessions, the appointment of a senior scientist as Executive Director to lead the Secretariat, and the institution of conflict of interest policies for major players in the IPCC assessment process. Moreover, the architecture of the Secretariat should be reevaluated to ensure that its responsibilities can be carried out effectively. As part of this reevaluation, the roles and responsibilities of key participants, including the IPCC Chair, should be clearly defined. A limit of one term for key IPCC leaders, including the IPCC Chair, Working Group Co-chairs, and the proposed Executive Director, would ensure a greater infusion of fresh perspectives on the assessments.

Recommendations:

- The IPCC should establish an Executive Committee to act on its behalf between Plenary sessions. The membership of the Committee should include the IPCC Chair, the Working Group Co-chairs, the senior member of the Secretariat, and 3 independent members, including some from outside of the climate community. Members would be elected by the Plenary and serve until their successors are in place.
- The IPCC should elect an Executive Director to lead the Secretariat and handle day-to-day operations of the organization. The term of this senior scientist should be limited to the timeframe of one assessment.
- The IPCC should redefine the responsibilities of key Secretariat positions both to improve efficiency and to allow for any future senior appointments.

- The IPCC should develop and adopt a rigorous conflict of interest policy that applies to all individuals directly involved in the preparation of IPCC reports, including senior IPCC leadership (IPCC Chair and Vice Chairs), authors with responsibilities for report content (i.e., Working Group Co-chairs, Coordinating Lead Authors, and Lead Authors), Review Editors, and technical staff directly involved in report preparation (e.g., staff of Technical Support Units and the IPCC Secretariat).
- The term of the IPCC Chair should be limited to the timeframe of one assessment.
- The terms of the Working Group Co-chairs should be limited to the timeframe of one assessment.

Strengthening the review process. The review process is a fundamental step for ensuring the quality of assessment reports. The Committee found that some existing IPCC review procedures are not always followed and that others are weak. In particular, Review Editors do not fully use their authority to ensure that review comments receive appropriate consideration by Lead Authors and that controversial issues are reflected adequately in the report. Staff support and/or clarification of the roles and responsibilities of Review Editors could help them provide the proper oversight. In addition, the large number of review comments may distract Lead Authors from fully addressing the most important issues. Having Review Editors identify the key issues that must be addressed would ensure that these issues receive due consideration. Allowing Lead Authors to document only their responses to noneditorial comments would reduce their administrative burden.

Recommendations:
- The IPCC should encourage Review Editors to fully exercise their authority to ensure that reviewers' comments are adequately considered by the authors and that genuine controversies are adequately reflected in the report.
- The IPCC should adopt a more targeted and effective process for responding to reviewer comments. In such a process, Review Editors would prepare a written summary of the most significant issues raised by reviewers shortly after review comments have been received. Authors would be required to provide detailed written responses to the most significant review issues identified by the Review Editors, abbreviated responses to all non-editorial comments, and no written responses to editorial comments.

Characterizing and communicating uncertainties. IPCC's guidance for addressing uncertainties in the Fourth Assessment Report urge authors to consider the amount of evidence and level of agreement about all conclusions and to apply subjective probabilities of confidence to conclusions when there was "high agreement, much evidence." However, such guidance was not always followed, as exemplified by the many statements in the Working Group II Summary for Policy Makers that are assigned high confidence, but are based on little evidence. Moreover, the apparent need to include statements of "high confidence" (i.e., an 8 out of 10 chance of being correct) in the Summary for Policy Makers led authors to make many vaguely defined statements that are difficult to refute, making them therefore of "high confidence." Such statements have little value. Scientific uncertainty is best communicated by indicating the nature, amount, and quality of studies on a particular topic, as well as the level of agreement among studies. The IPCC level-of-understanding scale provides a useful means of communicating this information.

Recommendations:

- All Working Groups should use the qualitative level-of-understanding scale in their Summary for Policy Makers and Technical Summary, as suggested in IPCC's uncertainty guidance for the Fourth Assessment Report. This scale may be supplemented by a quantitative probability scale, if appropriate.
- The confidence scale should not be used to assign subjective probabilities to ill-defined outcomes.
- Quantitative probabilities (as in the likelihood scale) should be used to describe the probability of well-defined outcomes only when there is sufficient evidence. Authors should indicate the basis for assigning a probability to an outcome or event (e.g., based on measurement, expert judgment, and/or model runs).
- The likelihood scale should be stated in terms of probabilities (numbers) in addition to words to improve understanding of uncertainty.
- Chapter Lead Authors should provide a traceable account of how they arrived at their ratings for level of scientific understanding and likelihood that an outcome will occur.
- Where practical, formal expert elicitation procedures should be used to obtain subjective probabilities for key results.

Developing an effective communications strategy. In the wake of errors discovered in the Fourth Assessment Report, the IPCC has come under severe criticism for the manner in which it has communicated with the media. The lack of an ongoing media-relations capacity and comprehensive communications strategy has unnecessarily placed the IPCC's reputation at risk and contributed to a decline in public trust of climate science.

Recommendation: The IPCC should complete and implement a communications strategy that emphasizes transparency, rapid and thoughtful responses, and relevance to stakeholders, and which includes guidelines about who can speak on behalf of IPCC and how to represent the organization appropriately.

Increasing transparency. Transparency is an important principle for promoting trust by the public, the scientific community, and governments. Interviews and responses to the Committee's questionnaire revealed a lack of transparency in several stages of the IPCC assessment process, including scoping and the selection of authors and reviewers, as well as in the selection of scientific and technical information considered in the chapters.

Recommendations:

- The IPCC should make the process and criteria for selecting participants for scoping meetings more transparent.
- The IPCC should develop and adopt formal qualifications and formally articulate the roles and responsibilities for all Bureau members, including the IPCC Chair, to ensure that they have both the highest scholarly qualifications and proven leadership skills.
- The IPCC should establish a formal set of criteria and processes for selecting Coordinating Lead Authors and Lead Authors.
- Lead Authors should explicitly document that a range of scientific viewpoints has been considered, and Coordinating Lead Authors and Review Editors should satisfy themselves that due consideration was given to properly documented alternative views.

Clarifying the use of unpublished and non-peer-reviewed sources. A significant amount of information that is relevant and appropriate for inclusion in IPCC assessments appears in the so-called gray literature, which includes technical reports, conference proceedings, statistics, observational data sets, and model output. IPCC procedures require authors to critically evaluate such sources and to flag the unpublished sources that are used. However, authors do not always follow these procedures, in part because the procedures are vague.

Recommendation: The IPCC should strengthen and enforce its procedure for the use of unpublished and non-peer-reviewed literature, including providing more specific guidance on how to evaluate such information, adding guidelines on what types of literature are unacceptable, and ensuring that unpublished and non-peer-reviewed literature is appropriately flagged in the report.

Engaging the best regional experts. The author team for each regional chapter in the Working Group II report is drawn largely from experts who live in the region. Yet some of the world's foremost experts on a particular region live outside the region. This geographic restriction sometimes limits the expertise that may be drawn upon for the regional assessments.

Recommendation: The IPCC should make every effort to engage local experts on the author teams of the regional chapters of the Working Group II report, but should also engage experts from countries outside of the region when they can provide an essential contribution to the assessment.

Expediting approval of the Summary for Policy Makers. The final language of the Summary for Policy Makers is negotiated, line-by-line, between scientists and government representatives in a grueling Plenary session that lasts several days, usually culminating in an all-night meeting. Both scientists and government representatives who responded to the Committee's questionnaire suggested changes to reduce opportunities for political interference with the scientific results and to improve the efficiency of the approval process.

Recommendation: The IPCC should revise its process for the approval of the Summary for Policy Makers so that governments provide written comments prior to the Plenary.

Reducing the growing burden on the scientific community. A successful assessment achieves an appropriate balance between the benefits of the results and the opportunity costs to the scientific community, such as diverting resources from ongoing research projects. *Analysis of Global Change Assessments* (NRC, 2007) found that high opportunity costs are a weakness of IPCC assessments. The Committee agrees, noting that each successive IPCC assessment has required greater amounts of human resources to assess the growing literature and to respond to the increasing number of review comments (e.g., see Figure 1.1). Without changes to the assessment process, the time may come when scientists reach the limit of their ability to produce a comprehensive assessment every five or six years. Scientists who responded to the Committee's questionnaire had a number of ideas for reducing opportunity costs. Among the most common was making the assessment reports shorter and less comprehensive by focusing on key issues or examining only significant new developments (see also Agrawala, 1998b; Karoly et

al., 2007). These shorter reports could either replace the comprehensive assessments or alternate with them. Posting supplementary information on the IPCC website (see further discussion below) could encourage authors to write less and to stay within their page limits. Increasing the efficiency of the review process, as discussed above, would also reduce the burden on scientists.

Maintaining flexibility. To its credit, the IPCC has shown that it is an adaptive organization, applying lessons learned from one assessment to the next and improving its processes to address new policy needs. For example, the IPCC adjusted the scope of Working Groups II and III after the first and second assessments (IPCC, 1992; Watson, 1997); substantially revised its principles and procedures after the second assessment (IPCC, 1998; 1999); and introduced a revised set of scenarios of socio-economic, climate and environmental conditions after the fourth assessment (IPCC, 2008). The Committee urges the IPCC to use the recommendations of this report to continue to adapt its process and structures to accommodate future advances in scientific understanding and evolving needs of policy makers.

Implementation

At the request of the UN Secretary General and the IPCC Chair, this report was completed in time for discussion at the 32nd session of the IPCC Plenary. Most of the Committee's recommendations can be implemented during the fifth assessment process and should be considered at the upcoming Plenary. These include recommendations to strengthen, modify, or enforce IPCC procedures, including the treatment of gray literature, the full range of views, uncertainty, and the review process. Recommendations that may require discussion at several Plenary sessions, but that could be implemented in the course of the fifth assessment, include those related to management, communications, and conflict of interest. Because the fifth assessment is already underway, it may be too late to establish a more transparent scoping process and criteria for selecting authors.

ISSUES FOR FUTURE CONSIDERATION

In the course of this review, a number of issues arose that are not central to the assessment processes and procedures covered by the Committee's task, but that affect the nature and quality of the assessment reports. These include the participation of developing countries and the private sector, access to data, the mandate of the Working Groups, and the timing of release of the assessment reports. Although the Committee came to no firm conclusions on these issues, they are raised here for consideration by the IPCC.

Participation of Developing Countries and the Private Sector

The level of participation of developing countries in the IPCC assessment process has been a concern since it was raised by Bert Bolin, the first IPCC Chair, in the early 1990s (Hulme and Mahony, 2010). Indeed, developing country participation has featured on the agenda of virtually every IPCC Bureau meeting from 1989 to 1996 (Agrawala, 1998b). Full participation by developing countries is necessary to build worldwide trust, confidence, and ownership in the process; to help sustain a global community of climate scientists; to create broad-based political

buy-in for the results; and to ensure that the assessment is framed in a way that accounts for the interests of all members and takes the fullest advantage of regional expertise (e.g., Lahsen, 2004).

Although capacity building is not in its mandate, the IPCC has made significant progress in increasing the participation of developing-country governments over the past two decades. In the first assessment, developing countries or countries with economies in transition accounted for 58 percent of the Panel membership; by the fourth assessment, the fraction had grown to 69 percent. However, although their numbers have increased, their contribution to all stages of the IPCC assessment process remains relatively low. Similarly, some progress has been made in increasing the number of scientists from developing countries that participate in the IPCC assessment process. Nevertheless, more than three-quarters of authors still come from developed countries.

The goal of having proportional representation by developing countries, both at the government level and among scientists, is not disputed either by the IPCC or the Committee. But clearly there is still some way to go if the increased number of developing country participants is not to be construed by some as geographic window-dressing rather than meaningful participation. A number of individuals who were interviewed or responded to the Committee's questionnaire observed that developing-country scientists often had limited understanding of developments outside of their region and/or did not do (or were not asked to do) their fair share of the work. Most attributed this lack of participation to the unique difficulties faced by developing-country scientists. These include the exclusive use of English to communicate during the preparation of the Working Group reports, the lack of support by their home institutions, poor access to literature, and the relatively small number of qualified scientists from some developing countries (e.g., see Liverman, 2008).

Overcoming these barriers will require an investment in scientific infrastructure by more nations, sustained investment in human capital in developing countries, and time. The recently launched IPCC fellowship program for vulnerable and developing countries, established with Nobel Prize funds, is a good example of how IPCC can play a direct role in developing the capacity of its climate research base. However, there are limits to what the IPCC can do to meet the capacity-building needs of developing countries. The IPCC can play an indirect role by encouraging international development organizations (e.g., the World Bank, Gates Foundation, the UK's Department for International Development), governments, and private companies to do what they can to build up human resources while carrying out their own objectives. The IPCC framework—in which scientists learn from their peers in other parts of the world while adding their own regional expertise and perspective—could be used as a model for training scientists from developing countries.

Development agencies and banks and other interested institutions could also help expand the scientific capacity available to the IPCC in other ways, including:

- Facilitating travel of developing-country scientists by funding mobility grants to and/or secondments (temporary placements) of developing-country Lead Authors to enable them to spend time in Technical Support Units or other appropriate institutions in developed countries to facilitate interaction, cooperation, and further human capital development;

- Establishing university-to-university partnerships to strengthen developing-country science; and
- Establishing regional facilities in developing countries where authors from the region could spend time interacting and writing.

Private companies often investigate important issues related to climate change, particularly in the areas of adaptation and mitigation. Many companies are beginning to see climate change as an opportunity, rather than a threat.[20] Their research and support of the process could significantly expand the available knowledge base concerning adaptation and mitigation options as well as the pool of well-qualified authors and reviewers. More fully entraining private companies into the assessment process increases the possibility of financial conflicts of interest, underscoring the importance of an IPCC conflict-of-interest policy.

Access to Information

Data are the bedrock on which the progress of science rests. The extraordinary development of new measuring techniques and new digital technologies has enabled climate scientists to assemble vast quantities of data. However, the large size and complex nature of these databases can make them difficult to access and use. Moreover, for various reasons many of these scientific databases as well as significant unpublished and non-peer-reviewed literature are not in the public domain. An unwillingness to share data with critics and enquirers and poor procedures to respond to freedom-of-information requests were the main problems uncovered in some of the controversies surrounding the IPCC (Muir Russell et al., 2010; PBL, 2010). Poor access to data inhibits users' ability to check the quality of the data used and to verify the conclusions drawn. Consequently, it is important for the IPCC to aspire toward ensuring that the main conclusions in its assessment reports are underpinned by appropriately referenced peer-reviewed sources or, to the greatest extent practical, by openly accessible databases. The Technical Support Units could play a key role in helping the IPCC work toward this goal.

In the future, the IPCC may want to consider implementing available technologies to improve its operational efficiency. Commercial databases and systems, for example, are available for managing nominations, citations, and drafts and revisions. Some emerging approaches also merit interest. In particular, the notion of a Wiki-style process was raised in presentations to the Committee[21] and in responses to the questionnaire. A Wiki-style process is an electronic, web-based system in which the available literature on climate change can be uploaded, critically reviewed, and synthesized with previous information in near real time. Some respondents have suggested testing the concept on a small scale, such as using Wiki pages to supplement the Working Group reports with information that is substantially more detailed than allowed by page limits and that is also more up-to-date. Others are working to develop the concept more fully.[22]

[20] See World Business Council for Sustainable Development, http://www.wbcsd.org/templates/TemplateWBCSD5/layout.asp?type=p&MenuId=NjY&doOpen=1&ClickMenu=LeftMenu.
[21] Presentations to the Committee by Robert Watson and John Christy on June 15, 2010.
[22] See the June 16, 2010, Draft Concept Note by Bob Watson and Rosina Bierbaum, prepared for the Climate Wiki Discussion Meeting, July 28-29, 2010, in Chicheley, United Kingdom.

Working Group Structure and Phasing of Reports

Although the IPCC adjusted the scope of Working Groups II and III after the first and second assessments (IPCC, 1992; Watson, 1997), the basic Working Group structure has remained consistent through all four assessments, despite some suggestions for change. For example, Hulme suggested dividing the assessment into global science, regional evaluation, and policy analysis (Hulme et al., 2010). A number of respondents to the Committee's questionnaire also offered suggestions for change, especially to Working Groups II and III, ranging from expanding their scope, to combining them, to eliminating them completely.

A key part of IPCC's scoping process is the reevaluation of the scope and mandate of the Working Groups, based on lessons learned from the previous assessment and future needs. In the next scoping process, the IPCC is encouraged to explore structural options that may help address the increasingly multidisciplinary nature of the science, without being constrained by historical precedent.

Regardless of the future structure of the Working Groups, it is likely that issues that cut across the Working Group mandates will arise throughout the assessment process, especially during the writing and reviewing of reports. Possible ways for fostering interactions among the Working Groups include designing key cross-Working Group issues into the scoping process, holding joint Working Group meetings as appropriate, and appointing reviewers from author teams in other Working Groups. Strengthening coordination across Working Groups where appropriate and productive would not only increase opportunities for knowledge transfer and synergy but would also provide a framework for integrating the various pieces of Working Group reports into the Synthesis Report.

Another issue that merits consideration by the Panel and the Bureau is the phasing of the Working Group reports. It is not clear to the Committee whether issuing all four reports of the assessment within one year is the most effective and efficient means of providing this information to policy makers. Advantages include ensuring that no Working Group report is outdated by the time the Synthesis Report is written. However, there are also disadvantages, particularly for Working Group II. In many regions there is a relatively small knowledge base in climate science and its impacts and also a relatively small cohort of available scholars. The Panel should consider whether the regional assessment should be released significantly later than the sector assessment in order to devote as many high-quality resources as possible to these important issues. In addition, it may be desirable to release the Working Group I report a few years ahead so the other Working Groups can take advantage of the results.

Given the short amount of time available for this review, the Committee could not address every issue of importance to the IPCC assessment process. Nevertheless, it is the hope of the Committee that this report will contribute to an ongoing dialog among IPCC stakeholders on a matter of importance to all humankind and that, as the IPCC embarks on its fifth assessment, the recommendations will encourage greater adherence to current procedures and strengthen IPCC's assessment process and management structure.

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Appendix A
Letters of Request to the IAC Co-Chairs

THE UNITED NATIONS

INTERGOVERNMENTAL PANEL ON Climate change

WMO UNEP

10 March 2010

Dear Dr. Dijkgraaf,

We are writing to request that the InterAcademy Council (IAC) conduct a thorough, independent review of the processes and procedures followed by the Intergovernmental Panel on Climate Change (IPCC) in preparing its Assessment Reports.

As you are aware, the IPCC was established in 1988 by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), in accordance with General Assembly Resolution 43/53, to provide policymakers with a comprehensive and objective scientific risk assessment of the current status of climate change and its potential consequences for both people and the planet. The Assessment Reports of the IPCC, which are endorsed by the world's governments, are made possible thanks to the efforts of thousands of scientists who voluntarily contribute their time and expertise. Over the years, these reports have provided much of the scientific foundation for climate policy, in particular for the United Nations Framework Convention on Climate Change (UNFCCC).

In recent months, a very small number of errors have been brought to light in the Fourth Assessment Report (AR4) of the IPCC, a document containing thousands of peer-reviewed and independent scientific studies. However, the bedrock scientific consensus on climate change as described in the Fourth Assessment Report remains unchanged, and indeed was reaffirmed by the world's environment ministers meeting last month in Bali, Indonesia.

Given the gravity of the global threat posed by climate change, it is vitally important to ensure full confidence in the scientific process underpinning the assessments of the IPCC. Governments and the public at large look to the IPCC as the world's most authoritative scientific body for assessing climate risk and informing climate policy.

Dr. Robbert H. Dijkgraaf
Co-chair
InterAcademy Council
Amsterdam

As the IPCC embarks on its Fifth Assessment Report (AR5), it is imperative that its work be as accurate, objective, comprehensive and transparent as possible, and that the potential for any future errors is minimized. It is vitally important that every step of the assessment process be clear, consistent, and comprehensible. The IPCC must also be able to respond quickly and transparently to any questions of its work, recognizing that the world now operates in a 24-hour media cycle.

To this end, we, the Secretary-General of the United Nations, along with the Chair of the IPCC, are requesting that the IAC conduct an independent review of the IPCC processes and its procedures for preparing future Assessment Reports. Please find Terms of Reference attached for this independent review.

Consultations for conducting such a review were carried out within the United Nations system, in particular with the organizations sponsoring the IPCC, WMO and UNEP, as well as with the Vice-Chairs and Co-Chairs of the IPCC. Consultations were also held in February 2010 with environment ministers and senior government officials at the 11th Special Session of the UNEP Governing Council and Global Ministerial Environment Forum. While expressing support for the unique role and value of the IPCC, ministers also recommended the need for an independent review of the processes and procedures of the IPCC.

UNEP and WMO, the parent organizations of the IPCC, have agreed to provide administrative support and channel the necessary government funds to support this review.

In order for the IPCC to benefit from the recommendations of the IAC in preparing its Fifth Assessment Report, we would ask you to submit your report by 31 August 2010. The results of the review will then be submitted for consideration and decision to the 32nd Session of the IPCC to be held in October 2010.

We would be grateful if you would accept this invitation, and look forward to a reply at your earliest convenience. A similar letter has been addressed to Dr. Lu Yongxiang.

Yours sincerely,

BAN Ki-moon
Secretary-General
United Nations

Dr. Rajendra K. Pachauri
Chairman
Intergovernmental Panel on Climate Change

THE UNITED NATIONS

ipcc
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

10 March 2010

Dear Dr. Lu,

We are writing to request that the InterAcademy Council (IAC) conduct a thorough, independent review of the processes and procedures followed by the Intergovernmental Panel on Climate Change (IPCC) in preparing its Assessment Reports.

As you are aware, the IPCC was established in 1988 by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), in accordance with General Assembly Resolution 43/53, to provide policymakers with a comprehensive and objective scientific risk assessment of the current status of climate change and its potential consequences for both people and the planet. The Assessment Reports of the IPCC, which are endorsed by the world's governments, are made possible thanks to the efforts of thousands of scientists who voluntarily contribute their time and expertise. Over the years, these reports have provided much of the scientific foundation for climate policy, in particular for the United Nations Framework Convention on Climate Change (UNFCCC).

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Given the gravity of the global threat posed by climate change, it is vitally important to ensure full confidence in the scientific process underpinning the assessments of the IPCC. Governments and the public at large look to the IPCC as the world's most authoritative scientific body for assessing climate risk and informing climate policy.

Dr. Lu Yongxiang
Co-chair
InterAcademy Council
Amsterdam

As the IPCC embarks on its Fifth Assessment Report (AR5), it is imperative that its work be as accurate, objective, comprehensive and transparent as possible, and that the potential for any future errors is minimized. It is vitally important that every step of the assessment process be clear, consistent, and comprehensible. The IPCC must also be able to respond quickly and transparently to any questions of its work, recognizing that the world now operates in a 24-hour media cycle.

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We would be grateful if you would accept this invitation, and look forward to a reply at your earliest convenience. A similar letter has been addressed to Dr. Robbert H. Dijkgraaf.

Yours sincerely,

BAN Ki-moon
Secretary-General
United Nations

Dr. Rajendra K. Pachauri
Chairman
Intergovernmental Panel on Climate Change

Independent Review of the IPCC Assessment Process

Terms of Reference

Background

By the 1980s, concerns about global climate change had become widespread. This catalyzed a demand for knowledge and action from governments, civil society, the UN and other stakeholders. Responding to the demand, and in keeping with UN General Assembly Resolution 43/53 of 6 December 1988, the United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO) established the Intergovernmental Panel on Climate Change (IPCC) in 1988 to provide the governments with objective, comprehensive and up–to-date information about climate change and its implications. Therefore, the initial task for the IPCC was to prepare a comprehensive review and recommendations with respect to the state of knowledge of the science of climate change; social and economic impacts of climate change, and possible response strategies and elements for inclusion in a possible future international convention on climate.

Since its creation, the IPCC has developed into a unique global assessment process that builds on broad participation of the best experts from different backgrounds and viewpoints, a robust multi-stage review process and strong partnership between the scientific community and the governments. The most important outputs of this process have been comprehensive scientific assessment reports about climate change released in 1990, 1995, 2001 and 2007. The reports provided authoritative policy-relevant, but not policy-prescriptive information on key aspects of climate, such as the physical science basis, impacts of and vulnerability to climate change in human and natural systems, options for adapting to impacts of climate change, and options for mitigation.

The IPCC is in the process of commencing work on its 5th Assessment Report. It has been IPCC practice that the Panel, which meets at least once a year at the level of government representatives, reviews its structure at the beginning of every assessment cycle and agrees on the scope and focus of the upcoming report. The structure and outline of the 5th Assessment Report have been agreed in the year 2009. The Panel also reviews its principles and procedures at regular intervals.

In view of the relevance of the IPCC assessments for global and sub-global policy-making processes, and to reduce the occurrence and minimize the potential impact of errors in the preparation of reports, further strengthening the IPCC processes and procedures is necessary to ensure continued scientific credibility of its assessments. A proposal to carry out a review of IPCC processes and procedures was communicated by the IPCC Secretariat to IPCC member governments in mid-February 2010. This was supported by environment ministers and government delegations at the 11th Session of the UNEP Global Ministerial Environment Forum held at Bali during 24-26 February 2010.

Subsequently, the United Nations Secretary-General and the Chair of the IPCC have come to the conclusion that an independent review of the IPCC process and the procedures for preparing reports is desirable. The executive heads of the founders of the IPCC, the Executive Director of UNEP, and the Secretary-General of WMO, concur with this conclusion. Collectively, they have decided to entrust this task to the InterAcademy Council (IAC), because it embodies the collective expertise and experience of national academies from all regions of the world. The IAC has agreed to undertake this task.

In carrying out this task, it is expected that the IAC, through its networks of national academies of sciences, will engage high-profile experts from relevant fields to prepare a report that presents recommendations on possible revisions of the IPCC procedures and other measures and actions. The recommendations will allow the IPCC to respond to future challenges and ensure ongoing quality of its reports. The review should pay attention to all IPCC Working Groups and the Task Force, and address the specific challenges by integrating different disciplines including from the physical, natural, social and economic sciences.

Scope, Objectives and Expected Outputs

In undertaking its work, the IAC will take into account the "Principles Governing IPCC Work", including their Appendices: Appendix A "Procedures for the preparation, review, acceptance, adoption, approval and publication of the IPCC reports" and its Annexes (hereinafter referred to as IPCC Procedures); Appendix B "Financial Procedures for the IPCC"; and Appendix C "Rules of Procedures for the Election of the IPCC Bureau and Any Task Force Bureau". It will also review IPCC policies and processes for admitting observer organizations and other relevant guidelines. The IAC will agree on its own rules of procedure and workplan, which clearly illustrate how it will ensure achieving the objectives of the review, including the modalities for necessary consultations.

The proposed terms of reference for the review are:

1. Review IPCC procedures for preparing reports including:
   - Data quality assurance and data quality control;
   - Guidelines for the types of literature appropriate for inclusion in IPCC assessments, with special attention to the use of non peer-reviewed literature;
   - Procedures for expert and governmental review of IPCC material;
   - Handling of the full range of scientific views; and
   - Procedures for correcting errors identified after approval, adoption and acceptance of a report.

2. Analyze the overall IPCC process, including the management and administrative functions within the IPCC, and the role of UNEP and WMO, the United Nations system and other relevant stakeholders, with a view to strengthen and improve the efficiency of the assessment work and effectively ensure the consistent application of the IPCC Procedures.

3. Analyze appropriate communication strategies and the interaction of the IPCC with the media to ensure that the public is kept apprised of its work.

4. Prepare a report on the outcome of the consultations referred to above, including:
   - Methodology of the report preparation and measures taken to ensure high quality of the report findings;
   - Recommendations for amendments to the IPCC procedures;

- Recommendations concerning strengthening the IPCC process, institutions and management functions;
- Any other related recommendations;
- Outline of a plan for the implementation of recommendations.

General Principles of Work

1. The IAC will conduct its work independently according to its procedures for carrying out expert studies. Other than providing relevant information, neither IPCC, WMO nor UNEP will have any oversight or control over the review process.

2. The Co-Chairs of the IAC will transmit the final report to the Office of the United Nations Secretary-General and the IPCC Secretariat, with copies to the Executive Director of UNEP, and the Secretary-General of WMO.

Support for the Independent Review

1. Experts contributing to the review will do so without any remuneration for their services.

2. UNEP and WMO will provide technical and secretarial support and financial resources, as requested by the IAC and as mutually agreed.

Schedule of the Independent Review

Because the organizational work for the Fifth Assessment Report of the IPCC has already begun, it is urgent that the IAC submits its report at the latest by 31 August 2010, to allow for the submission of a document for consideration at the 32nd Session of the IPCC in October 2010. Timely submission is essential to allow governments to consider the Report in advance of the Session and to be prepared to decide on actions that may be necessary. In this way the findings of the review can be built into the fifth assessment cycle in its early stages.

Appendix B
Questionnaire on IPCC Processes and Procedures

1. What role(s), if any, have you played in any of the IPCC assessment processes?

2. What are your views on the strengths and weaknesses of the following steps in the IPCC assessment process? Do you have any recommendations for improvement?

   a. Scoping and identification of policy questions
   b. Election of bureau including working group chairs
   c. Selection of lead authors
   d. Writing of working group reports
   e. Review processes
   f. Preparation of the Synthesis report, including the Summary for Policy Makers
   g. Adoption of report by the IPCC plenary
   h. Preparation of any special reports

3. What is your opinion on the way in which the full range of scientific views is handled?

4. Given the intergovernmental nature of IPCC, what are your views on the role of governments in the entire process?

5. Given that IPCC assessments consider a vast amount of literature, what are your views and suggestions for improvement on the sources of data and the comprehensiveness of the literature used, including non-peer-reviewed literature?

6. What are your views and suggestions regarding the characterization and handling of uncertainty in each of the working group reports and the synthesis report?

7. What is your view of how IPCC handles data quality assurance and quality control and identification and rectification of errors, including those discovered after publication?

8. What is your view of how IPCC communicates with the media and general public, and suggestions for improving it?

9. Comment on the sustainability of the IPCC assessment model. Do you have any suggestions for an alternative process?

10. Do you have any suggestions for improvements in the IPCC management, secretariat, and/or funding structure to support an assessment of this scale?

11. Any other comments

Appendix C
Contributors to the Review

The following individuals provided oral or written input to the Committee:

Tony Abraham
Pramod Aggarwal, Indian Agricultural Research Institute, India
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Nathan Bindoff, University of Tasmania, Australia
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Jonathan Doig
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Brian Gray, Environment Canada, Canada
Dave Griggs, Monash University, UK
Michael Grubb, Climate Strategies, UK
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Erik Haites, Margaree Consultants Inc., Canada
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Joshua Halpern, Howard University, USA
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Clive Hammond, UK
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Charles D.D. Howard, Canada
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Gordon Hughes, University of Edinburgh, UK
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Michel Jarraud, WMO, France
Julie Johnston, GreenHeart Education, Canada
Phillip Jones, University of East Anglia, UK
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Randy Julander, United States Department of Agriculture, USA
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Thomas Karl, National Oceanic and Atmospheric Administration, USA
Prasad Kasibhatla, Duke University, UK
Bob Kates, Brown University (emeritus), USA
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Appendix D
Excerpts of IPCC Procedures

SELECTION OF LEAD AUTHORS (IPCC, 1999, Section 4.4.2)

Coordinating Lead Authors and Lead Authors are selected by the relevant Working Group/Task Force Bureau, under general guidance and review provided by the Session of the Working Group or, in case of reports prepared by the Task Force on National Greenhouse Gas Inventories, the Panel, from those experts cited in the lists provided by governments and participating organisations, and other experts as appropriate, known through their publications and works. The composition of the group of Coordinating Lead Authors and Lead Authors for a section or chapter of a Report shall reflect the need to aim for a range of views, expertise and geographical representation (ensuring appropriate representation of experts from developing and developed countries and countries with economies in transition). There should be at least one and normally two or more from developing countries. The Coordinating Lead Authors and Lead Authors selected by the Working Group/Task Force Bureau may enlist other experts as Contributing Authors to assist with the work.

PROCEDURE FOR USING NON-PUBLISHED/NON-PEER-REVIEWED SOURCES IN IPCC REPORTS (IPCC, 1999, Annex 2)

Because it is increasingly apparent that materials relevant to IPCC Reports, in particular, information about the experience and practice of the private sector in mitigation and adaptation activities, are found in sources that have not been published or peer-reviewed (e.g., industry journals, internal organisational publications, non-peer reviewed reports or working papers of research institutions, proceedings of workshops etc) the following additional procedures are provided. These have been designed to make all references used in IPCC Reports easily accessible and to ensure that the IPCC process remains open and transparent.

1. Responsibilities of Coordinating, Lead and Contributing Authors

Authors who wish to include information from a non-published/non-peer-reviewed source are requested to:

a. Critically assess any source that they wish to include. This option may be used for instance to obtain case study materials from private sector sources for assessment of adaptation and mitigation options. Each chapter team should review the quality and validity of each source before incorporating results from the source into an IPCC Report.
b. Send the following materials to the Working Group/Task Force Bureau Co-Chairs who are coordinating the Report:

- One copy of each unpublished source to be used in the IPCC Report
- The following information for each source:

- Title
- Author(s)
- Name of journal or other publication in which it appears, if applicable
- Information on the availability of underlying data to the public
- English-language executive summary or abstract, if the source is written in a non English language
- Names and contact information for 1-2 people who can be contacted for more information about the source.

2. Responsibilities of the Review Editors

The Review Editors will ensure that these sources are selected and used in a consistent manner across the Report.

3. Responsibilities of the Working Group/Task Force Bureau Co-Chairs

The Working Group/Task Force Bureau Co-Chairs coordinating the Report will (a) collect and index the sources received from authors, as well as the accompanying information received about each source and (b) send copies of unpublished sources to reviewers who request them during the review process.

4. Responsibilities of the IPCC Secretariat

The IPCC Secretariat will (a) store the complete sets of indexed, non-published sources for each IPCC Report not prepared by a working group/the Task Force on National Greenhouse Gas Inventories (b) send copies of non-published sources to reviewers who request them.

5. Treatment in IPCC Reports

Non-peer-reviewed sources will be listed in the reference sections of IPCC Reports. These will be integrated with references for the peer-reviewed sources. These will be integrated with references to the peer reviewed sources stating how the material can be accessed, but will be followed by a statement that they are not published.

IPCC REVIEW PROCESS (IPCC, 1999, Section 4 and Annex 1)

4.1 Introduction to Review Process

The review process generally takes place in three stages: expert review of IPCC Reports, government/expert review of IPCC Reports, government review of the Summaries for Policymakers, Overview Chapters and/or the Synthesis Report. Working Group/Task Force Bureau Co-Chairs should aim to avoid (or at least minimise) the overlap of government review periods for different IPCC Reports and with Sessions of the Conference of Parties of the United Nations Framework Convention of Climate Change and its subsidiary bodies.

Expert review should normally be eight weeks, but not less than six weeks, except to the extent decided by the Panel. Government and government/expert reviews should not be less than eight weeks, except to the extent decided by the Panel.

All written expert, and government review comments will be made available to reviewers on request during the review process and will be retained in an open archive in a location determined by the IPCC Secretariat on completion of the Report for a period of at least five years.

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4.2.4 Review

Three principles governing the review should be borne in mind. First, the best possible scientific and technical advice should be included so that the IPCC Reports represent the latest scientific, technical and socio-economic findings and are as comprehensive as possible.

Secondly, a wide circulation process, ensuring representation of independent experts (i.e. experts not involved in the preparation of that particular chapter) from developing and developed countries and countries with economies in transition should aim to involve as many experts as possible in the IPCC process. Thirdly, the review process should be objective, open and transparent.

To help ensure that Reports provide a balanced and complete assessment of current information, each Working Group/Task Force Bureau should normally select two Review Editors per chapter (including the executive summaries) and per technical summary of each Report.

Review Editors should normally consist of a member of the Working Group/Task Force Bureau, and an independent expert based on the lists provided by governments and participating organisations. Review Editors should not be involved in the preparation or review of material for which they are an editor. In selecting Review Editors, the Bureaux should select from developed and developing countries and from countries with economies in transition, and should aim for a balanced representation of scientific, technical, and socio-economic views.

4.2.4.1 First Review (by Experts)

First draft Reports should be circulated by Working Group/Task Force Bureau Co-Chairs for review by experts selected by the Working Group/Task Force Bureaux and, in addition, those on the lists provided by governments and participating organisations, noting the need to aim for a range of views, expertise, and geographical representation. The review circulation should include:

- Experts who have significant expertise and/or publications in particular areas covered by the Report.

- Experts nominated by governments as Coordinating Lead Authors, Lead Authors, contributing authors or expert reviewers as included in lists maintained by the IPCC Secretariat.
- Expert reviewers nominated by appropriate organisations.

The first draft Reports should be sent to Government Focal Points, for information, along with a list of those to whom the Report has been sent for review in that country.

The Working Group/Task Force Bureau Co-Chairs should make available to reviewers on request during the review process specific material referenced in the document being reviewed, which is not available in the international published literature.

Expert reviewers should provide the comments to the appropriate Lead Authors through the relevant Working Group/Task Force Bureau Co-Chairs with a copy, if required, to their Government Focal Point.

Coordinating Lead Authors, in consultation with the Review Editors and in coordination with the respective Working Group/Task Force Bureau Co-Chairs and the IPCC Secretariat, are encouraged to supplement the draft revision process by organising a wider meeting with principal Contributing Authors and expert reviewers, if time and funding permit, in order to pay special attention to particular points of assessment or areas of major differences.

4.2.4.2 Second Review (by Governments and Experts)

A revised draft should be distributed by the appropriate Working Group/Task Force Bureau Co-chairs or through the IPCC Secretariat to governments through the designated Government Focal Points, and to all the coordinating lead authors, lead authors and contributing authors and expert reviewers.

Governments should send one integrated set of comments for each Report to the appropriate Working Group/Task Force Bureau Co-chairs through their Government Focal Points.

Non-government reviewers should send their further comments to the appropriate Working Group/Task Force Bureau Co-Chairs with a copy to their appropriate Government Focal Point.

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Annex 1: Tasks and Responsibilities

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4. Expert Reviewers

Function: To comment on the accuracy and completeness of the scientific/technical/socio-economic content and the overall scientific/technical/socio-economic balance of the drafts.

Comment: Expert reviewers will comment on the text according to their own knowledge and experience. They may be nominated by Governments, national and international organisations, Working Group/Task Force Bureaux, Lead Authors and Contributing Authors.

5. Review Editors

Function: Review Editors will assist the Working Group/Task Force Bureaux in identifying reviewers for the expert review process, ensure that all substantive expert and government review comments are afforded appropriate consideration, advise lead authors on how to handle contentious/controversial issues and ensure genuine controversies are reflected adequately in the text of the Report.

Comment: There will be one or two Review Editors per chapter (including their executive summaries) and per technical summary. In order to carry out these tasks, Review Editors will need to have a broad understanding of the wider scientific and technical issues being addressed. The workload will be particularly heavy during the final stages of the Report preparation. This includes attending those meetings where writing teams are considering the results of the two review rounds. Review Editors are not actively engaged in drafting Reports and cannot serve as reviewers of those chapters of which they are Authors. Review Editors can be members of a Working Group/Task Force Bureau or outside experts agreed by the Working Group/Task Force Bureau.

Although responsibility for the final text remains with the Lead Authors, Review Editors will need to ensure that where significant differences of opinion on scientific issues remain, such differences are described in an annex to the Report. Review Editors must submit a written report to the Working Group Sessions or the Panel and where appropriate, will be requested to attend Sessions of the Working Group and of the IPCC to communicate their findings from the review process and to assist in finalising the Summary for Policymakers, Overview Chapters of Methodology Reports and Synthesis Reports. The names of all Review Editors will be acknowledged in the Reports.

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UNCERTAINTY GUIDANCE FOR THE FOURTH ASSESSMENT REPORT (IPCC, 2005b)

The following notes are intended to assist Lead Authors (LAs) of the Fourth Assessment Report (AR4) to deal with uncertainties consistently. They address approaches to developing expert judgments, evaluating uncertainties, and communicating uncertainty and confidence in findings that arise in the context of the assessment process. Where alternative approaches are used in the relevant literature, those should be used but where possible related to the approaches given here. Further background material and more detailed coverage of these issues are available in the guidance paper on uncertainties developed for the Third Assessment Report [1] and the report of an IPCC Workshop on Uncertainty and Risk [2].

The working group reports will assess material from different disciplines and will cover a diversity of approaches to uncertainty, reflecting differences in the underlying literature. In particular, the nature of information, indicators and analyses used in the natural sciences is quite different from that used in the social sciences. WG I focuses on the former, WG III on the latter, and WG II covers both. The purpose of this guidance note is to define common approaches and language that can be used broadly across all three working groups. Each working group may need to supplement these notes with more specific guidance on particular issues consistent with the common approach given here.

Plan to treat issues of uncertainty and confidence

1. Consider approaches to uncertainty in your chapter at an early stage. Prioritize issues for analysis. Identify key policy relevant findings as they emerge and give greater attention to assessing uncertainties and confidence in those. Avoid trivializing statements just to increase their confidence.

2. Determine the areas in your chapter where a range of views may need to be described, and those where LAs may need to form a collective view on uncertainty or confidence. Agree on a carefully moderated (chaired) and balanced process for doing this.

Review the information available

3. Consider all plausible sources of uncertainty using a systematic typology of uncertainty such as the simple one shown in Table 1. Many studies have shown that structural uncertainty, as defined in Table 1, tends to be underestimated by experts [3]. Consider previous estimates of ranges, distributions, or other measures of uncertainty and the extent to which they cover all plausible sources of uncertainty.

Table 1. A simple typology of uncertainties

Type	Indicative Examples of Sources	Typical Approaches or Considerations
Unpredictability	Projections of human behaviour not easily amenable to prediction (e.g. evolution of political systems). Chaotic components of complex systems.	Use of scenarios spanning a plausible range, clearly stating assumptions, limits considered, and subjective judgments. Ranges from ensembles of model runs.
Structural uncertainty	Inadequate models, incomplete or competing conceptual frameworks, lack of agreement on model structure, ambiguous system boundaries or definitions, significant processes or relationships wrongly specified or not considered.	Specify assumptions and system definitions clearly, compare models with observations for a range of conditions, assess maturity of the underlying science and degree to which understanding is based on fundamental concepts tested in other areas.
Value uncertainty	Missing, inaccurate or non-representative data, inappropriate spatial or temporal resolution, poorly known or changing model parameters.	Analysis of statistical properties of sets of values (observations, model ensemble results, etc); bootstrap and hierarchical statistical tests; comparison of models with observations.

4. Assess issues of risk where supported by published work. Where probabilistic approaches are available, consider ranges of outcomes and their associated likelihoods with attention to outcomes of potential high consequence. An alternative approach is to provide information for decisions that would be robust in the sense of avoiding adverse outcomes for a wide range of future possibilities [4]. (Note that the term "risk" has several different usages. If used it should be defined in context.)

Make expert judgments

5. Be prepared to make expert judgments and explain those by providing a traceable account of the steps used to arrive at estimates of uncertainty or confidence for key findings – e.g. an agreed hierarchy of information, standards of evidence applied, approaches to combining or reconciling multiple lines of evidence, and explanation of critical factors.

6. Be aware of a tendency for a group to converge on an expressed view and become overconfident in it [3]. Views and estimates can also become anchored on previous versions or values to a greater extent than is justified. Recognize when individual views are adjusting as a result of group interactions and allow adequate time for such changes in viewpoint to be reviewed.

Use the appropriate level of precision to describe findings

7. Assess the current level of understanding on key issues and precede statements on confidence or uncertainty with a general summary of the corresponding state of knowledge. Table 2 below provides a consistent language for this.

8. Develop clear statements for key findings that are quantitative and give explicit time frames as far as possible. Define carefully the corresponding variables or outcomes, their context, and any conditional assumptions. Where scenarios are used, explain the range of assumptions and how they affect the outcome. Then consider the most appropriate way to describe the relevant uncertainties or level of confidence by going as far down the hierarchy given below as you feel appropriate (from expressions of less to more confidence and less to more probabilistic approaches) [5]:

A. *Direction of change is ambiguous or the issue assessed is not amenable to prediction:* Describe the governing factors, key indicators, and relationships. If a trend could be either positive or negative, explain the pre-conditions or evidence for each.
B. *An expected trend or direction can be identified (increase, decrease, no significant change):* Explain the basis for this and the extent to which opposite changes would not be expected. Include changes that have a reasonable likelihood even where they are not certain. If you describe a collective level of confidence in words, use the language options in Table 2 or 3.
C. *An order of magnitude can be given for the degree of change (i.e. sign and magnitude to within a factor of 10):* Explain the basis for estimates given and indicate assumptions made. The order of magnitude should not change for reasonable ranges in such

assumptions. If you describe a collective level of confidence in words, use the language options in Table 2 or 3.

D. *A range can be given for the change in a variable as upper and lower bounds, or as the 5th and 95th percentiles, based on objective analysis or expert judgment:* Explain the basis for the range given, noting factors that determine the outer bounds. If you cannot be confident in the range, use a less precise approach. If you describe a collective level of confidence or likelihood of an outcome in words, use the language options in Tables 3 or 4.

E. *A likelihood or probability of occurrence can be determined for an event or for representative outcomes, e.g. based on multiple observations, model ensemble runs, or expert judgment:* State any assumptions made and estimate the role of structural uncertainties. Describe likelihoods using the calibrated language given in Table 4 or present them quantitatively.

F. *A probability distribution can be determined for changes in a continuous variable either objectively or through use of a formal quantitative survey of expert views*: Present the PDF graphically and/or provide the 5th and 95th percentiles of the distribution. Explain the methodology used to produce the PDF, any assumptions made, and estimate the role of structural uncertainties.

Communicate carefully, using calibrated language

9. Be aware that the way in which a statement is framed will have an effect on how it is interpreted [6]. (A 10% chance of dying is interpreted more negatively than a 90% chance of surviving.) Use neutral language, avoid value laden statements, consider redundant statements to ensure balance (e.g. chances of dying and of surviving), and express different but comparable risks in a consistent way.

10. To avoid the uncertainty perceived by the reader being different from that intended, use language that minimizes possible misinterpretation and ambiguity. Note that terms such as "virtually certain", "probable", or "likely", can engage the reader effectively, but may be interpreted very differently by different people unless some calibration scale is provided [7].

11. Three forms of language are given in Tables 2, 3 and 4 to describe different aspects of confidence and uncertainty and to provide consistency across the AR4.

12. Table 2 considers both the amount of evidence available in support of findings and the degree of consensus among experts on its interpretation. The terms defined here are intended to be used in a relative sense to summarize judgments of the scientific understanding relevant to an issue, or to express uncertainty in a finding where there is no basis for making more quantitative statements. A finer scale for describing either the amount of evidence (columns) or degree of consensus (rows) may be introduced where appropriate, however, if a mid-range category is used authors should avoid over-using that as a 'safe' option that communicates little information to the reader. Where the level of confidence is '*high agreement much evidence*', or where otherwise appropriate, describe uncertainties using Table 3 or 4.

Table 2. Qualitatively defined levels of understanding

Level of agreement or consensus →

High agreement limited evidence	...	High agreement much evidence
...	...	...
Low agreement limited evidence	...	Low agreement much evidence

Amount of evidence (theory, observations, models) →

13. A *level of confidence*, as defined in Table 3, can be used to characterize uncertainty that is based on expert judgment as to the correctness of a model, an analysis or a statement. The last two terms in this scale should be reserved for areas of major concern that need to be considered from a risk or opportunity perspective, and the reason for their use should be carefully explained.

Table 3. Quantitatively calibrated levels of confidence

Terminology	Degree of Confidence in Being Correct
Very high confidence	At least 9 out of 10 chance of being correct
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

14. *Likelihood*, as defined in Table 4, refers to a probabilistic assessment of some well defined outcome having occurred or occurring in the future. The categories defined in this table should be considered as having 'fuzzy' boundaries. Use other probability ranges where more appropriate but do not then use the terminology in table 4. Likelihood may be based on quantitative analysis or an elicitation of expert views. The central range of this scale should not be used to express a lack of knowledge – see paragraph 12 and Table 2 for that situation. There is evidence that readers may adjust their interpretation of this likelihood language according to the magnitude of perceived potential consequences [8].

Table 4. Likelihood Scale

Terminology	Likelihood of the Occurrence/Outcome
Virtually certain	> 99% probability of occurrence
Very likely	> 90% probability
Likely	> 66% probability
About as likely as not	33 to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Exceptionally unlikely	< 1% probability

15. Consider the use of tabular, diagrammatic or graphical approaches to show the primary sources of uncertainties in key findings, the range of outcomes, and the factors and relationships determining levels of confidence.

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Appendix E
Committee Biographies

Harold T. SHAPIRO, President Emeritus of Princeton University and the University of Michigan, is a Professor of Economics and Public Affairs in the Department of Economics and the Woodrow Wilson School of Public and International Affairs at Princeton University. His fields of special interest in economics include econometrics, bioethics, science policy and the evolution of postsecondary education. He joined the faculty of the University of Michigan, where in 1977 he was named Vice President for Academic Affairs and elected President in 1980. In 1988, he took office as President of Princeton University, serving in that position until 2001 when he became President Emeritus. He continued to teach during his presidencies at both Princeton and Michigan. He served as a member and Vice Chair of the President's Council of Advisors on Science and Technology from 1990 to 1992 during the administration of President George H.W. Bush. He also served President Bill Clinton's administration as Chair of the National Bioethics Advisory Commission from 1996 to 2001. He is author of several books, including A Larger Sense of Purpose: Higher Education and Society (Princeton University Press, 2005). In 2000 he received the Council of Scientific Society Presidents Citation for Outstanding Leadership. In 2008, he was awarded the Clark Kerr Medal for Distinguished Leadership in Higher Education, presented annually by the University of California, Berkeley, Academic Senate. He also received the William D. Carey Award for leadership in Science Policy from the American Association for the Advancement of Science. He is an elected member of the Institute of Medicine of the United States National Academy of Sciences and the American Philosophical Society. He is a Fellow of the College of Physicians of Philadelphia, an active Member of the European Academy of Sciences and Arts, and a Fellow of the American Association for the Advancement of Science. Dr. Shapiro received his undergraduate degree from McGill University in 1956 and his Ph.D. from Princeton in 1964, both in economics.

Roseanne DIAB is the Executive Officer of the Academy of Science of South Africa (ASSAf) and Emeritus Professor and Honorary Senior Research Associate at the University of KwaZulu-Natal in Durban. She is a member of ASSAf and is recognized for her research contributions in the field of atmospheric sciences, particularly air quality and tropospheric ozone. She chairs the Editorial Board of the South African Journal of Science, and serves on the Editorial boards of the South African Geographic Journal, and Atmospheric Environment. Prof. Diab has been a Fulbright senior research scholar, and has served as a member of a number of international commissions, including the Commission on Atmospheric Chemistry and Global Pollution (CACGP), the International Ozone Commission (IOC) and the Scientific Steering Committee of Stratospheric Ozone Processes and their Role in Climate (SPARC). She is a fellow of the South African Geographical Society and of the University of Natal. Dr. Diab has a Ph.D. in Environmental Sciences from the University of Virginia, Charlottesville (USA).

Carlos Henrique de BRITO CRUZ is the Scientific Director of the São Paulo Research Foundation (FAPESP), in Brazil, and Professor at the "Gleb Wataghin" Physics Institute at the University of Campinas (Unicamp). Previously he served as Rector of the University of Campinas (Unicamp; 2002-2005), President of FAPESP (1996-2002), Dean of Research at Unicamp (1994-1998) and as Director of the Gleb Wataghin Physics Institute at Unicamp (1991-

1994 and 1998-2002). From 1995 to 1999 served as Vice-President of the Brazilian Physics Society (SBF). Prof. Brito Cruz served in several committees in funding agencies, science related organizations and universities and presently he presides the Council for Technology and Competitiveness at the Federation of Industries of the State of São Paulo (FIESP) and is a member of the Telefónica I+D Advisory Board and the Microsoft Research External Research Advisory Board. His research interests are the study of ultrafast phenomena using femtosecond lasers, in which he leads a research laboratory at the Physics Institute at Unicamp, and science policy. He authored or co-authored more than 100 scientific papers and conference presentations, supervised 11 Doctoral Thesis (two in co-supervision) and 10 Master Dissertations (one as co-supervisor). In 2000 he was awarded the Order of Scientific Merit by the President of Brazil for his contributions to science and technology, and in 2004 he received the "Conrado Wessel" General Science Prize for his scientific career. Prof. Brito Cruz has been faculty at Unicamp since 1982. During 1986 and 1987 he worked as a resident visitor at AT&T Bell Laboratories in Holmdel, New Jersey and in 1990 he had a three-month visitor engagement at Bell Labs, Murray Hill, New Jersey. Prof. Brito Cruz also worked short terms as a visitor at the Quantum Optics Laboratory at the University of Rome (1981-1982) and at the Laboratoire de Physique des Solides at the Université Pierre and Marie Curie in Paris (1988). Prof. Brito Cruz graduated in Electronics Engineering from the Aeronautics Technology Institute (ITA) in 1978, received a M.Sc. degree in physics in 1980, and a D.Sc. degree in physics in 1983, both from the "Gleb Wataghin" Physics Institute at Unicamp. He is a member of the Academy of Sciences of the State of São Paulo (ACIESP) and the Brazilian Academy of Sciences (ABC).

Maureen CROPPER is a Professor of Economics at the University of Maryland, a Senior Fellow at Resources for the Future, and a former Lead Economist at the World Bank. She has served as chair of the Environmental Protection Agency's Science Advisory Board Environmental Economics Advisory Committee and as president of the Association of Environmental and Resource Economists. She is a member of the United States National Academy of Sciences and a Research Associate of the National Bureau of Economic Research. Her research has focused on valuing environmental amenities (especially environmental health effects), on the discounting of future health benefits, and on the tradeoffs implicit in environmental regulations. Her current research focuses on energy efficiency in India, on the impact of climate change on migration, and on the benefits of collective action in pandemic flu control. Dr. Cropper received a B.A. in Economics from Bryn Mawr College (summa cum laude, 1969) and a Ph.D. in Economics from Cornell University (1973).

FANG Jingyun is Cheung Kong Professor and Chair, Department of Ecology, College of Urban and Environmental Sciences, Peking University, in Beijing. He also serves as Academic Director of the College of Urban and Environmental Sciences, where he also taught as a professor from 1997 to today. His research interests include terrestrial carbon cycle, biodiversity and biogeography of plants, and applications of remote sensing in ecology. From 1995 to 1997, he was Senior Scientist and Associate Director at Key Laboratory of Systems Ecology, Chinese Academy of Science. He worked as an assistant from May 1989 to November 1992, then as an associate scientist from December 1992 to December 1994 in the Center for Eco-Environmental Sciences, Chinese Academy of Sciences. He is a member of the Academy of Sciences for the Developing World (TWAS) and the Chinese Academy of Sciences. He has been awarded the HeLiangHeLi Science and Technology Progress Award (Life Science); Chang Jiang Scholars

Achievement Award, China Ministry of Education and Hong Kong Li Ka Shing Foundation; National Natural Science Award of the State Council (the second class); and Natural Science Award of the China Ministry of Education (the first class). He was also recipient of the Yangtze Scholarship, China Ministry of Education and Yangtze Group. Dr. Fang holds a Ph.D. in biology from Osaka City University (Osaka, Japan).

Louise O. FRESCO is currently University Professor, University of Amsterdam, The Netherlands where she concentrates on issues of sustainability, food and agriculture, and scientific policy. She is a recognized global leader in issues of food and agriculture and a member of the Royal Netherlands Academy of Arts and Sciences, and foreign member of the Royal Swedish Academy of Agriculture and Forestry and the Spanish Real Academia de Ingeniería. She worked at the United Nations Food and Agriculture Organization (FAO) from 1997 through to 2006 – first as Director of Research, Extension and Training, and later as Assistant Director-General covering agriculture, biodiversity, water, climate change, soils, plant animal production, veterinary health and food and nutrition. At the FAO, she oversaw major reforms toward more flexibility in responding to worldwide agricultural crises and increased collaboration with the private sector and nongovernmental organizations. She has extensive understanding of international environmental negotiations and UN processes and has participated in many of the major environmental treaty meetings. Dr. Fresco obtained a Ph.D. in tropical agronomy (cum laude) from Wageningen University. She held the chair of professor of plant production systems and led the Department of Agronomy, where she pioneered many interdisciplinary research programs, including land use and soil nutrient modeling. She has published over 100 scientific papers and three books (while reports written while at the UN were not published by name), and hundreds of articles on popular science in Dutch. She served extensively on boards and evaluation committees for several Consultative Group on International Agricultural Research (CGIAR) centers. She was the founding chair of LUCC, a joint IGBP and IHDP program on climate, land use, and cover change. She is a member of the Socio-Economic Council of The Netherlands, the highest advisory body of the country. Beyond her scientific work, she serves as a non-executive director of Unilever International and as a board member of Rabobank, one of the largest cooperative banks in the world. She is deeply committed to shaping policy on sustainable agriculture and food consumption, the effects of climate change on vegetation and land use, and forging partnerships between the scientific, government and the non-governmental and private sector communities.

Syukuro MANABE is a meteorologist who pioneered the use of computers to simulate global warming and natural climate variations. He is currently a senior meteorologist at the Program in Atmospheric and Oceanic Science, Princeton University. Working at the Geophysical Fluid Dynamics Laboratory of the National Oceanic and Atmospheric Administration (NOAA), first in Washington, D.C. and later in Princeton, New Jersey, he worked with director Joseph Smagorinsky to develop three-dimensional models and applied them to studying climatic change. In 1958, he came to the United States to work at the General Circulation Research Section of the U.S. Weather Bureau, now the Geophysical Fluid Dynamics Laboratory of NOAA, continuing until 1997. He also served as a lecturer with the rank of professor in the Atmospheric and Ocean Science Program at Princeton University. From 1997 to 2001, he worked at the Frontier Research System for Global Change in Japan serving as Director of the Global Warming Research Division. He is a member of the United States National Academy of Sciences, and a

foreign member of Japan Academy, Academia Europaea and the Royal Society of Canada. In 1992, he was the first recipient of the Blue Planet Prize of the Asahi Glass Foundation. In 1997 he was awarded the Volvo Environmental Prize from the Volvo Environmental Foundation. He has also been honored with the American Meteorological Society's Carl-Gustaf Rossby Research Medal, the American Geophysical Union's Revelle Medal, and the Milutin Milankovitch Medal from the European Geophysical Society. Dr. Manabe received a Ph.D. from the University of Tokyo in 1958.

Goverdhan MEHTA is National Research Professor and Lilly-Jubilant Chair, School of Chemistry, University of Hyderabed, Hyderabed, India. He is a leading researcher in the area of chemical sciences and specializes in the area of organic chemistry. He is author of over 400 research papers and has delivered over 200 lectures in major conferences around the world. He is on the editorial boards of leading international journals in chemical sciences and organic chemistry and serves on the advisory boards of many research and development outfits and foundations worldwide. He has previously held positions as the Director of the Indian Institute of Science (1998-2005) and the President (Vice Chancellor) of the University of Hyderabad (1994-1998). He has been the President of the Indian National Science Academy (1999-2001), founding Co-Chair of the InterAcademy Council (2001-2006), and President of the International Council for Science (2005-2008). He is a Fellow of the Royal Society, Foreign Member of the Russian Academy of Sciences, and Fellow of the Academy of Sciences of the Developing World (TWAS). Among the more than 30 medals and awards and numerous honorary doctorate degrees, he was awarded the civilian honor of Padma Sri (2000) by the President of India and Chevalier de la Legion d'Honneur (2004) by the President of France. He is deeply interested in issues related to science and policy, science for sustainable development and is passionately committed to promoting and fostering international collaboration in science and technology with the object of bridging the knowledge divide.

Mario MOLINA was a co-recipient (along Paul J. Crutzen and F. Sherwood Rowland) of the 1995 Nobel Prize in Chemistry for his role in elucidating the threat to the Earth's ozone layer of chlorofluorocarbon gases. Between 1974 and 2004, he held research and teaching posts at the University of California, Irvine, the Jet Propulsion Laboratory at Caltech, and the Massachusetts Institute of Technology (MIT) where he was an institute professor. On July 1, 2004, he joined the Department of Chemistry and Biochemistry and the Center for Atmospheric Sciences at the Scripps Institution of Oceanography at the University of California, San Diego. He is a member of the Pontifical Academy of Sciences, United States National Academy of Sciences, United States Institute of Medicine, and El Colegio Nacional of Mexico. He serves on the board of the John D. and Catherine T. MacArthur Foundation, and he also sits on the U.S. President's Committee of Advisors in Science and Technology. He is president of the Center for Strategic Studies in Energy and the Environment in Mexico City. He has also received more than 20 honorary degrees. Asteroid 9680 Molina is named in his honor. After completing his basic studies in Mexico City and Switzerland, Dr. Molina earned a bachelor's degree in chemical engineering at the National Autonomous University of Mexico in 1965; a postgraduate degree from the Albert Ludwigs University of Freiburg, West Germany in 1967; and a doctoral degree in chemistry from the University of California, Berkeley, in 1972. He was an author of the IPCC fourth assessment report.

Sir Peter WILLIAMS FRS is Honorary Treasurer and Vice President of the Royal Society and Chairman of the National Physical Laboratory. He is a Trustee of Marie Curie Cancer Care. Previously, he was Chancellor of the University of Leicester, a non-executive director of GKN plc and of W.S. Atkins plc, Chairman and Chief Executive of Oxford Instruments plc, Deputy Chief Executive of VG Instruments Ltd., Master of St. Catherine's College Oxford, Chairman of Trustees of the Science Museum, Chairman of the Engineering & Technology Board, and Chairman of the Particle Physics and Astronomy Research Council. He was knighted in 1998 and is a Fellow of the Royal Society and of the Royal Academy of Engineering. Sir Peter has a Ph.D. in physics from Cambridge and began his academic career in Cambridge and Imperial College and then moved into private industry in 1975, returning to academic life as Master of St. Catherine's Oxford in 2000.

Ernst-Ludwig WINNACKER is Secretary General of the Human Frontier Science Program (HSFP). He was the first Secretary General of the European Research Council (January 2007 - June 2009). In 1980 he took up the position of Full Professor at the Institute of Biochemistry at the Ludwig Maximilians University of Munich. From 1984 to 1997, he was Director of the Laboratory of Molecular Biology, the University of Munich Gene Center. From 1998 onwards he served as President of the German Research Foundation (DFG), a position he held until the end of 2006. From 2003 to 2004 he was Chairman of the European Heads of Research Councils (EUROHORCs). Among other memberships, he is a member of the Institute of Medicine of the U.S. National Academies and of the German National Academy of Sciences Leopoldina. Dr. Winnacker holds a Dr. honoris causa from the University of Veterinary Medicine in Vienna. He is the recipient of the 2009 International Science and Technology Cooperation Award of the People's Republic of China, of the Order of the Rising Sun, Gold and Silver Star of Japan (2009), and of the Commanders' Cross of the Order of Merit of the Republic of Poland (2007). He was named a Chevalier de la Legion d'Honneur in 2006 and received the Commander's Cross of the Order of Merit of the Federal Republic of Germany in 2006. Dr. Winnacker who is the author of several books and textbooks, among them "From Genes to Clones", studied chemistry at the Swiss Federal Institute of Technology (ETH Zurich) where he obtained his Ph.D. in 1968, and completed post-doctorates at the University of California in Berkeley and the Karolinska Institute in Stockholm from 1968 to 1972.

ZAKRI Abdul Hamid is Science Advisor to the Government of Malaysia, advising the Prime Minister and the Cabinet on issues related to science, technology, and innovation. He holds the Tuanku Chancellor Chair at Universiti Sains Malaysia. He was the former Director of the Institute of Advanced Studies, United Nations University, and Co-Chair of the Millennium Ecosystem Assessment. He is a member of the Arab Fund Fellowship Program, Senior Advisory Group on Technical Assistance and Cooperation of the International Atomic Energy Agency (IAEA), and the Executive Board of International Council for Science (ICSU). He served as the Secretary General of the Society for the Advancement of Breeding Researches in Asia and Oceania (SABRAO) from 1981-1989 and was Deputy Vice-Chancellor at Universiti Kebangsaan Malaysia from 1992-2000. He was the Founding President of the Genetics Society of Malaysia. His professional interests include biodiplomacy, education for sustainable development, and biotechnology and biodiversity policies for developing countries. Recipient of a Fulbright-Hays Fellowship (1981) and a Gold Medal Award from the Rotary Research Foundation (1999), he is a Fellow of the Academy of Sciences Malaysia, the Academy of Sciences of the Developing

World (TWAS), the World Academy of Art and Science, and the Islamic World Academy of Sciences. In 1998 he received the Langkawi Award, a national laureate for outstanding contribution in the field of environment in Malaysia. Three species known to science are named after him: a beetle (Paleosepharia zakrii); a cicada (Pomponia zakrii), and a pitcher plant (Nepenthes zakriana).

Appendix F
Acronyms and Abbreviations

AR4	Fourth Assessment Report
CLA	Coordinating Lead Author
FAQ	Frequently Asked Questions
FAR	First Assessment Report
IAC	InterAcademy Council
IPCC	Intergovernmental Panel on Climate Change
LA	Lead Author
NAS	National Academy of Sciences
NRC	National Research Council
RE	Review Editor
SAR	Second Assessment Report
SRES	Special Report on Emissions Scenarios
TAR	Third Assessment Report
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization