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From Assessment to Policy: Lessons Learned from the U.S. National Assessment

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ABSTRACT

The process of translating scientific information into timely and useful insights that inform policy and resource management decisions, despite the existence of uncertainties, is a difficult and challenging task. *Policy-focused assessment* is one approach to achieving this end. It is an ongoing process that engages both researchers and end-users to analyze, evaluate and interpret information from multiple disciplines to draw conclusions that are timely and useful for decision makers.

This paper discusses key characteristics of a policy-focused assessment process, including (1) ongoing collaboration between the research, assessment, and stakeholder communities; (2) a focus on stakeholder information needs; (3) multidisciplinary approaches; (4) use of scenarios to deal with uncertainties; and (5) evaluation of risk management options. We illustrate the particular challenge to assessors of providing the specific types of insights stakeholders need to effectively influence policy decisions. And we discuss the role that assessment can play in formulating an agenda for future research.

Examples from the U.S. National Assessment of "The Potential Consequences of Climate Variability and Change for the United States" are used to illustrate a policy-focused assessment process. For many of the participants, the first U.S. National Assessment was an extraordinary learning experience about how to develop better ways of conducting assessments.

Key Words: climate change, U.S. National Assessment, regional assessment, sector assessment, policy-focused assessment, consequences.

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INTRODUCTION

In American society, despite periodic calls for smaller, less intrusive government, policy makers are expected to protect the public from many threats, seen and unseen, natural and manufactured. These calls for protection require policy makers to marshal America's scientific and technological sophistication to identify potential risks and solutions in order to protect public health, the environment, and social well-being.

A number of emerging, "global" environmental problems like climate change, losses of biodiversity, depletion of stratospheric ozone, and the dieback of coral reefs, pose a particular challenge for policy makers. These problems pose potentially significant risks to different segments of society, but they also may be costly to address. In many cases, the sources of the problems are large in number and diverse, and any remedy is likely to affect a broad cross-section of society. This may create a dilemma for policy makers who must balance the interests and well- being of their many constituents while responsibly addressing the risks. The search for solutions can be contentious.

Typical of this type of challenge is global climate change. Climate change poses both risks and opportunities. Whether a particular impact of climate change is a risk or opportunity may vary within regions, sectors and demographic groups and may disproportionately burden or provide advantages to these affected segments. Similar concerns may also exist with regard to proposed adaptive and mitigative responses. These distributional concerns increase the challenges associated with climate change. Further, many of the effects of climate change are occurring simultaneously in multiple media (*e.g.,* changes in air quality; changes in water quantity and quality) and in multiple sectors (*e.g.,* public health, agriculture, forestry, recreation, and tourism). The systemic nature of this problem poses a particular challenge to decision makers and resource managers.

Finding politically acceptable solutions to the problem has been elusive. Policy makers are challenged by the need to make decisions despite the existence of extensive scientific uncertainties and the inability of scientists to make absolute predictions about future outcomes. Debates about acceptable levels of risk are often contentious, especially because the costs of remediation are potentially high. The persistent, long-term nature of climate change also forces policy makers to confront the extent to which they are willing to discount future benefits – including the welfare of future generations — to delay remedial actions.

To cope with complex environmental problems like climate change, policy makers must employ new approaches that enable them to analyze and interpret uncertain scientific information in order to make timely and effective decisions. Also, any approach taken must "democratize" the nexus of science and policy to reduce the contentiousness of discussions over potential solutions. All stakeholders — those parties with specific interests in the issue or measures to address it — should be given the opportunity to participate in the process of evaluating acceptable levels of risk and appropriate responses.

One approach, called *policy-focused assessment*, is playing an increasingly important role in society's efforts to deal with global environmental problems. Policy-focused assessment is an ongoing *process* that engages both researchers and end-users to

analyze, evaluate and interpret information from multiple disciplines to draw conclusions that are both timely and useful for decision makers (National Assessment Working Group 1999).[1] Throughout this process, key research gaps are identified and research needs prioritized in order to produce the information needed to better answer the questions being asked by policy makers and resource managers over time. On a periodic basis, assessment *products* are produced using the best-available scientific and socioeconomic information to inform a particular set of policy decisions. Timely production of these products is critical since decisions, including the decision to do nothing, are often made whether or not the scientific community is prepared to provide input (Scheraga and Smith 1990).

An essential characteristic of a policy-focused assessment is ongoing collaboration and interaction among the research, assessment, and stakeholder communities (the latter of which often includes policy makers). Scientific research can help identify new risks and opportunities. At any point in time, researchers need to share the best-available scientific information with stakeholders, provide information and data required for an assessment, and inform policy decisions through the assessment process. In turn, assessments can help identify important knowledge gaps and prioritize research needs that must be filled in order to better answer existing–and new–questions being asked by the stakeholder community. Constant feedback between these parallel processes is essential.

However, although science should inform policy decisions, it is important to ensure that the science remains unbiased. Policy decisions should reflect the values of society, based on scientific insights when appropriate. The information needs of stakeholders should help frame scientific research planning. But the scientific research itself should be apolitical, and results must never be influenced by political interests.

This paper discusses the key characteristics and components of a policy-focused assessment, and the challenge of ensuring that assessments provide the specific types of insights stakeholders need to effectively influence policy decisions. The characteristics discussed in this paper include: (1) ongoing collaboration between the research, assessment, and stakeholder communities; (2) a focus on stakeholder needs; (3) multidisciplinary approaches; (4) use of scenarios to deal with uncertainties; and (5) evaluation of risk management options.

The process of assessment is illustrated using examples from the first U.S. National Assessment of "The Potential Consequences of Climate Variability and Change on the United States," mandated by Congress in the Global Change Research Act of 1990. This assessment was delivered to Congress in November 2000. It consists of

1 The National Assessment Working Group actually uses the term "policy-relevant," which it defines as "an iterative analytic process that engages both analysts and end-users to evaluate and interpret the interactions of dynamic physical, biological, and social systems and communicate useful insights in a timely fashion." We have chosen to refer to this type of assessment as "policy-focused." We recognize that many types of research and assessment activities may, at some point in time, be relevant for policy, but are not focused on answering specific questions being asked by policy makers. Policy-focused assessments are intended to inform in a timely fashion decision makers asking specific questions. Our terminology is intended to distinguish between these different types of assessment activities.

16 regional assessments and five sectoral assessments, as well as an overall synthesis report. For many of the participants, the first U.S. National Assessment was an extraordinary learning experience — in the development of the assessment process as a partnership between different communities (*e.g.*, the research, assessment, and stakeholder communities; governmental and nongovernmental entities), the synthesis and communication of complex issues pertaining to the implications of climate change, and the formulation of an agenda of future research directions derived from a growing understanding of the needs for and limitations of knowledge available for such an assessment.[2]

Examples are also provided from the National Acid Precipitation Assessment Program (NAPAP), which delivered its first assessment to Congress in 1991 (National Acid Precipitation Assessment Program 1991). The NAPAP assessment summarized the findings of a 10-year effort to understand the potential impacts of acidic deposition on the United States.

Both the NAPAP assessment and the first U.S. National Assessment provide valuable insights and lessons about how a policy-focused assessment process should be structured and conducted.

GOALS AND CHARACTERISTICS OF POLICY-FOCUSED ASSESSMENT

The goal of policy-focused assessment is to inform policy decisions in a timely fashion using the best available scientific and socioeconomic information. A policy-focused assessment is more than just a traditional risk assessment or toxicological study. It also is more than just a synthesis of scientific information or an evaluation of the state of the science. Rather, it involves the analysis of information from multiple disciplines — including the social and economic sciences — to answer the specific questions being asked by stakeholders. And it includes an analysis of adaptation options to improve society's ability to respond effectively to risks and opportunities as they emerge.

A successful policy-focused assessment engages, and is of mutual benefit to, three (not necessarily distinct) communities: researchers, assessors, and stakeholders. Such a stakeholder-oriented process helps the research and assessment communities ensure the timeliness and usefulness of their work. But significant benefits also accrue to stakeholders, particularly for their understanding of the issues and for their decision-making processes. Stakeholders are presented with the best-available scientific information at the outset of an assessment and informed about current scientific understanding of the potential implications of climate change. This can assist them in formulating and asking questions that, in turn, help focus the assessment. The assessment process can then motivate stakeholders to include climate change as part of their thinking and decisions. And the assessment itself can yield results that may have important implications for ensuing policy and decision making.

For an assessment to be informative, the assessors must know the particular issues and questions of interest to stakeholders. Stakeholders should be engaged from the

2 This observation was made by an anonymous reviewer of an earlier draft of this manuscript.

outset of the assessment process and then involved in the analytic process on an ongoing basis. Openness and inclusiveness enable different participants to bring a diversity of views and information that may benefit the assessment process. Also, including all interested parties makes the assessment process more transparent and credible.

For an assessment to be timely, the assessors must understand how the information will be used by the relevant stakeholders and the time frame within which the information is needed. Even with stakeholder involvement, research scientists often are reluctant to make any statements that might be used by policy makers because scientific uncertainties still exist. Yet, policy makers often have to make decisions under uncertainty, whether or not scientists are prepared to inform those decisions.[3] Assessors strive to answer decision makers' questions to the extent possible given uncertain science, in the belief that informed decisions are better than uninformed decisions. They also characterize the uncertainties and explore their implications for different policy or resource management decisions in the belief that a better understanding of the quality and implications of scientific information leads to more informed decisions.

For an assessment to be informative when significant scientific uncertainties exist that make it impossible to make specific predictions or forecasts of future outcomes, a scenario approach might be used. Such an approach was used in the U.S. National Assessment process. Scenarios are plausible alternative futures that "paint a picture"of what might happen under particular assumptions. However, they are not specific predictions or forecasts. Rather, they provide a starting point for investigating questions about an uncertain future and for visualizing alternative futures in concrete and human terms. Using scenarios helps to identify vulnerabilities and explore potential response strategies (National Assessment Synthesis Team 2000). In the U.S. National Assessment, results from several state-of-the-science climate models and data from historical observations were used to generate a variety of such scenarios. The primary model results used were produced by the Hadley Centre in the United Kingdom and the Canadian Centre for Climate Modeling and Analysis.

In some cases, however, the state of knowledge about potential consequences of climate change may not be sufficient to support any modeling. This was the case with the Health Sector Assessment (Bernard and Ebi 2001). In such cases, assessors might rely upon expert judgement and existing peer-reviewed studies to provide qualitative insights to stakeholders.

A Stakeholder-Oriented Activity

A successful assessment process entails elicitation from stakeholders of the issues, questions and outcomes of greatest concern to them. The U.S. National Assessment

3 One anonymous reviewer has noted that scientific uncertainty comes from at least two sources. First, insufficient or conflicting data may exist, so scientists agree that there is a lot of uncertainty. Second, different scientists may interpret the same data in different ways, or may disagree on the importance or relevance of different findings. The reviewer has suggested that both of these sources of uncertainty were important in the U.S. National Assessment, but the latter type of uncertainty tended to lead to more contentious arguments between scientists.

was a stakeholder-oriented process. Several important lessons about the engagement of stakeholders were learned during the course of the first National Assessment:

1. It is sometimes difficult to identify all of the interested stakeholders at the outset of an assessment process.

2. It is not always obvious at the outset of an assessment process what issues will be of concern to stakeholders.

3. Stakeholders and assessors are not necessarily distinct communities.

4. Stakeholders must be continuously engaged throughout an assessment process, and it is particularly important to reevaluate the level of stakeholder concern and to identify any new issues of concern to stakeholders as they are informed of assessment results.

It is sometimes difficult to immediately identify all constituencies that might have an interest — a stake — in a particular environmental problem. One of the lessons of the National Assessment has been that new stakeholders often are identified during the course of an assessment process. Consider the experience of the assessors working on the Health Sector Assessment that was one component of the U.S. National Assessment.[4] At the outset of the Health Sector Assessment, the lead authors defined the stakeholders as "people within private, nonprofit, and government entities (local, state, federal) focused specifically on public health issues" (Bernard and Ebi 2001).[5] Yet, it became clear during the course of the assessment that other constituents had a potential interest in the issue. For example, questions about how climate change might affect the frequency of weather-related accidents revealed an issue of interest to the insurance industry. Other interests may be revealed as our understanding of the potential health consequences of climate change evolves. The lesson from this experience is that the process of identifying and involving stakeholders must be an ongoing process.

In addition to the challenge of identifying potential stakeholders, it is not always obvious at the outset of an assessment process what issues will be of concern to stakeholders. To address this problem, a workshop was held at the outset of each

4 The authors of this paper were closely involved in the planning of the U.S. National Assessment process, as well as the conduct of the Mid-Atlantic Regional Assessment, the Great Lakes Regional Assessment, and Health Sector Assessment referred to in this paper. The first phases of these assessments were successfully completed, and provide excellent examples of how to properly conduct a policy-focused assessment. They also are used by the authors to illustrate the important next steps that should be undertaken in an ongoing assessment process.

5 The Health Sector Assessment authors realized that the universe of people interested in the health impacts of climate change is huge. They also realized that their working definition needed to be narrowed in a way that made outreach feasible during the first phase of the assessment. Given that their ultimate aim was interactive, policy-focused assessment, they decided that stakeholders would be defined as people with private, nonprofit, and government entities that are specifically focused on public health issues.

regional and sectoral assessment conducted as part of the U.S. National Assessment, and researchers, assessors, and stakeholders were invited. Researchers presented the best-available information about the potential consequences of climate variability and change for the sector or region. Given this information, stakeholders then articulated their concerns about climate change impacts in the context of other major issues they face. In the workshops and subsequent consultations, stakeholders identified priority regional and sector concerns, mobilized specialized expertise, identified potential adaptation options, and provided useful information for decision makers (National Assessment Synthesis Team 2000).

To illustrate the difficulty in identifying issues of concern to stakeholders at the outset of an assessment process, consider the experience of assessors conducting the Mid-Atlantic Regional Assessment (Fisher *et al.* 2000). At the outset of the assessment process, the assessors wanted to select a manageable set of potential consequences to examine. Based on their understanding of the science and what they thought would be the vulnerable sectors of interest to stakeholders in the region, they planned to focus on the impacts to agriculture, forests, and water quality and quantity. However, at a workshop to begin the assessment process and initiate relationships with stakeholders, the stakeholders expressed an interest in natural hazards and diseases like cholera, malaria, and other emerging diseases.

The assessors did not expect these additional issues to be of concern to the stakeholders because they didn't believe that they posed the greatest risks in the region. Yet they proceeded to examine them during the assessment for three reasons. First, it was important to be responsive to the stakeholder interests to ensure the usefulness of the assessment results. Second, it was important to demonstrate to the stakeholders that their willingness to be responsive was genuine and that the assessment would be focused on their needs and concerns. The trust of the stakeholders is important to an assessment, and to ignore stakeholder concerns at the outset of the process would have violated that trust. Third, the assessors felt that they had to consider the additional consequences of climate change identified by the stakeholders in order to confirm their own prior expectations that these consequences were not significant. They recognized that only a formal assessment of the potential consequences of climate variability and change could lead to a meaningful prioritization of problems for the region (Fisher *et al.* 1997).

Another lesson from the U.S. National Assessment is that assessors and stakeholders are not necessarily distinct communities. In many cases, the stakeholder community can offer data, analytic capabilities, insights and understanding of relevant problems that can contribute to the assessment. For example, assessors working on the Great Lakes Regional Assessment (Sousounis *et al.* 1998) learned that they could work with representatives of the commercial and recreational boating industry to gather information and insights on the impacts of lower lake levels on shipping and recreation.

Stakeholders can also be an important source of information for the research community and can help guide the research agenda. For example, stakeholder input is an essential component in the identification of relevant "indicators" of ecosystem health that might be monitored and studied. The research community has an important perspective of what are appropriate indicators of ecosystem health (*e.g.*, a forest ecosystem). However, whether or not a forest ecosystem can be

considered "healthy" is also a function of end uses. A forest that would be considered "healthy" by campers and hikers might be considered "unhealthy" by a commercial timber company. Consequently, such determinations should include both stakeholders and scientists.

The danger of failing to engage the stakeholders is illustrated by an exchange between NAPAP officials and Senator Patrick Moynihan at a 1990 Congressional hearing. At the end of the 10-year NAPAP program, Senator Moynihan — a proponent of the program — inquired about the implications of acidic deposition for the lakes of the northeast, if the problem went unabated. The response given by NAPAP officials to his questions was a set of scenarios describing projected changes in acidic neutralizing capacity. Dissatisfied with the answer, Senator Moynihan rephrased his question: "Are the fish going to die?" The NAPAP researchers failed to link changes in acidic neutralizing capacity to the effect of concern to stakeholders in the northeast, *i.e.*, changes in fish mortality. They also failed to consider other confounding factors that might have affected fish populations, including human responses to acidification, such as the liming of lakes to reduce acidity, or the seasonal restocking of fish. A true "integrated" assessment would have considered these factors in an attempt to answer the stakeholders' questions. The lesson to be learned from this example is that it is imperative that researchers and assessors elicit from stakeholders the specific questions that they want answered ("Are the fish going to die?"), undertake research that will help answer the questions, and then frame the insights gained from any assessment in terms that are meaningful to the stakeholders and that help inform the questions and decisions that follow. However, it is vital that the research be undertaken to address the questions that stakeholders have, not to provide the answers that they want to hear.

Assessment is an ongoing, iterative process. With the completion of the first round of sector and regional assessments conducted as part of the first U.S. National Assessment, the assessors are now beginning to return to the stakeholders to share what they have learned. They are also beginning to elicit from the stakeholders new interests and concerns that they might now have given the new insights provided by the assessment. And they are beginning to understand the public's willingness to undertake particular adaptation strategies.

Assessment is a Multidisciplinary Endeavor

Because of the complexity of the issues involved, policy-focused assessment requires insights from multiple, diverse disciplines. A lesson learned from both the U.S. National Assessment and the 1990 Assessment of the National Acid Precipitation Assessment Program (NAPAP) is that assessment teams must be composed of researchers from a variety of disciplines working together to address complex questions.

Consider NAPAP's experience trying to assess the potential damages to different materials, including galvanized steel and painted surfaces, due to acidic deposition (NAPAP 1991; Scheraga *et al.* 1990). For 9 of the first 10 years of NAPAP, this effort was dominated by physical scientists who focused primarily on the development of damage functions for galvanized steel. No effort was made to engage researchers from other disciplines who might have questioned whether the focus on galvanized

steel was appropriate. In the tenth year, economists were engaged in the assessment, and they asked just such a question. Through several bounding exercises, they examined the uses of different materials and their life cycles. These exercises revealed that the use of galvanized steel was declining over time, as was the stock of galvanized steel products. For example, cement barriers were replacing steel guard rails on the nation's highways for safety reasons. In addition, remaining uses for galvanized steel had short life cycles and tended to be replaced before acidic deposition could cause any damage. On the other hand, the stock of painted surfaces was much larger, longer lived, and more highly valued than the stock of galvanized surfaces. Therefore, the overall conclusion was that the potential damages to painted surfaces from acidic deposition were much larger than the potential damages to surfaces made of galvanized steel.

Had this bounding exercise been conducted at the beginning of the assessment, researchers might have concentrated their efforts on painted surfaces and delivered information to policy makers that had more significant implications for the economic well-being of society. Assessments are designed to respond to questions that do not necessarily respect the boundaries between different social and natural science disciplines. It is essential that the different disciplines work closely together from the outset of the assessment process.

Policy-Focused Assessment Includes Evaluation of Risk Management Options

In addition to consulting with stakeholders to establish an assessment's goals, and establishing a cooperative environment for researchers from multiple disciplines to work in, an assessment should include an analysis of society's ability to effectively respond to risks and opportunities as they emerge. This goes beyond the scope of a traditional risk assessment or toxicological study, but in order to be useful to policy makers, a consideration of risk management options is essential.

The first U.S. National Assessment built policy-relevance into the design of the assessment itself. The designers of the assessment process posed four questions to all of the assessors at the outset of the effort:

1. What are the current conditions of the region/sector and the existing stressors other than climate variability and change?

2. How will climate variability and change exacerbate or ameliorate the existing stresses?

3. What are the possible coping strategies for reducing the risks – or for taking advantage of the opportunities – posed by climate change?

4. What are the key research gaps identified by the assessment?

The first two questions focus on risk assessment. The third question focuses on risk management options. The assessment designers intended that the assessment inform decision makers who want to understand the implications of climate variability and change for the decisions they regularly make. They wanted to inform

resource managers who inevitably would ask, "What should we do differently — or the same — in the face of climate variability and change?"

Question 3 of the U.S. National Assessment was intentionally phrased as "What are the potential coping strategies...," rather than "What are the *best* coping strategies...," in order to avoid having the assessors inappropriately make policy decisions. A policy-focused assessment should be policy-relevant and inform decision makers, but it should not make specific policy recommendations.

The choice of a "best" policy is a decision that inherently depends upon social values and selection criteria that must be identified by decision makers (not by researchers or assessors). Policy decisions are often complex because of the need to consider multiple social objectives, and the need to assess the importance and relevance of these objectives in some consistent way (Julius and Scheraga 2000). The choice of a specific best coping strategy may depend upon considerations other than climate change, such as equity considerations (both within and across generations) and political feasibility. The policy decision will also likely depend upon a project's affordability, since strategies for coping with climate change compete for scarce resources that could be used to address other societal problems (*e.g.,* health care and poverty). Also, the choice of a best coping strategy may depend upon specific environmental objectives chosen by society, such as the protection of unique ecosystems (*e.g.,* the Everglades) or sustainable development goals.

A policy-focused assessment must be divorced from the actual process in which policy decisions are made in order to maintain the credibility, usefulness, and effectiveness of the assessment process. All parties participating in an assessment process, including decision makers relying upon the results of the assessment, must perceive the process as being apolitical and unbiased.

It can be challenging to avoid perceptions of bias given stakeholder involvement in the assessment process — stakeholders that often include the people making the actual policy decisions. Stakeholder involvement is necessary to ensure the timeliness and usefulness of the assessment results. But if the assessment is to maintain its effectiveness, no group of stakeholders can be allowed to "drive" the assessment results — nor be perceived as doing so. The assessment cannot be seen as being done to justify a particular stakeholder policy. Otherwise, the assessment will fail to facilitate the development of politically acceptable solutions and to overcome the contentious debates about climate change. This is why seeking out a broad array of stakeholders is important. It makes it harder for one viewpoint to dominate.

The fourth question was intended to identify key remaining research gaps that limited the assessors' ability to answer the questions being asked by the stakeholders. It also was intended to ascertain any new or different questions that the stakeholders might want answered, given the information gleaned from the first National Assessment. These new questions also might require that specific research activities be undertaken.

FROM ASSESSMENT TO POLICY

Assessments are useful to the extent that they can inform policy and resource management decisions. The first U.S. National Assessment has produced a wealth of information and insights that can, with further analysis, inform policy decisions.

But the process has not yet been completed. Additional analyses still have to be done to fully answer the risk management question (question #3) posed to all of the regional and sectoral assessors.

We present several examples that illustrate the challenge of having an assessment provide decision makers with the very specific type of information that will, in fact, be useful to them and influence their decisions. The first three examples highlight the fact that decision makers often need very specific types of information in order for them to incorporate climate change into their decision making, and to formulate and implement new and effective adaptive responses. The fourth example focuses on potential strategies for coping with vector-borne diseases and illustrates the fact that some adaptation measures may bring risks of their own. Decision makers need to be informed about the relative risks associated with alternative adaptation strategies, as well as the risks associated with climate change itself.

Example 1: Enabling Health Officials to Cope with Heat Stress

The assessment team working on the Health Sector Assessment systematically addressed each of the four questions posed in the U.S. National Assessment (Patz *et al.* 2000). They carefully reviewed the current status of health care in the United States. In collaboration with the public health community, they identified five categories of health outcomes that are most likely to be affected by climate change. These included: temperature-related morbidity and mortality; health effects of extreme weather events (storms, tornadoes, hurricanes, and precipitation extremes); air-pollution-related health effects; water- and food-borne diseases; and vector- and rodent-borne diseases.[6] They then evaluated, to the extent possible given current scientific uncertainties, the potential consequences of climate change for these health outcomes, and identified key research gaps (Table 1).

The Health Sector Assessment found that "at present, most of the U.S. population is protected against adverse health outcomes associated with weather and/or climate, although certain demographic and geographic populations are at increased risk." It concludes that "vigilance in the maintenance and improvement of public health systems and their responsiveness to changing climate conditions and to identified vulnerable subpopulations should help to protect the U.S. population from any adverse health outcomes of projected climate change."

The particular assessment of the potential consequences of heat stress for human mortality provided several useful insights. First, even under current conditions, people die of heat stress, and these are preventable deaths. Second, the elderly, very young, poor, and infirm are the most vulnerable populations.

From these insights, the assessors drew two conclusions. First, since heat and heat waves are projected to increase in severity and frequency with increasing global mean temperatures, climate change poses a risk to human health; in the absence of adaptation, more people may die of heat stress during summertime months. How-

6 The assessment authors clearly state, however, that other health outcomes identified in the literature and by stakeholders as potentially affected by climate variability and change may warrant future study, but are beyond the scope of the first assessment.

Table 1. Research needs identified in the Health Sector Assessment.

Heat-related morbidity and mortality
- improvement of the early prediction of these events by determining the key weather parameters associated with health
- improvement of urban design to facilitate trees, shade, wind and other heat-reducing conditions to limit the "urban heat island effect"
- better personal exposure assessment
- heat mortality modeling
- understanding of weather relationship to causes of winter mortality

Extreme weather events - related health effects
- improvement of warning systems to provide early, easily understood messages to the populations most likely to be affected
- evaluation of the effectiveness of educational materials and early warning systems
- long-term health effects from severe events, such as nutritional deficiency and mental health effects
- standardization of information collection after disasters to better measure morbidity and mortality
- effects of altered land use on vulnerability to extreme weather

Air pollution-related health effects
- association between weather and pollutants
- health impacts of chronic exposure to high levels of ozone
- health effects of exposure to ozone in people with asthma and other lung diseases
- interaction of ozone with other air pollutants
- mechanisms responsible for the adverse effects of ozone and other air pollutants in the general population and within susceptible subgroups
- measures that can modulate the impact of air pollution on health, such as nutrition and other life-style characteristics
- urban weather modeling for inversions, *etc.*

Water- and food-borne diseases
- links between land use and water quality, through better assessment at the watershed level of the transport and fate of microbial pollutants associated with rain and snowmelt
- methods to improve surveillance and prevention of water-borne disease outbreaks
- epidemiologic studies
- molecular tracing of water-borne pathogens
- links between drinking water, recreational exposure, and food-borne disease monitoring
- links between marine ecology and toxic algae
- vulnerability assessment to improve water and waste water treatment systems

Vector- and rodent-borne diseases
- improvement rapid diagnostic tests for pathogens
- vaccines
- improvement of active laboratory-based disease surveillance and prevention systems at the state and local level
- transmission dynamics (including reservoir host and vector ecology) studies
- improvement of surveillance systems for the arthropod vector and vertebrate hosts involved in the pathogen maintenance/transmission cycle to allow for more accurate predictive capability for epidemic/epizootic transmission
- more effective and rapid electronic exchange of surveillance data

ever, milder winters could reduce the number of deaths in winter months.[7] Second, people do not have to die of heat stress in the future. There is evidence that heat-related illnesses and deaths are largely preventable through behavioral adaptations, such as the use of air conditioning and increased fluid intake.

These are important conclusions, and they indicate to the public health community and the public at large that, although the U.S. may be capable of coping with the health consequences of climate change, we must anticipate public health needs and adapt. However, to influence decision making, the assessment would be more useful if it went a bit further. If these are preventable deaths, why aren't we preventing them? Are we surprised by the heat waves? Do some people not understand that they should drink more fluids and keep cool? Or does it cost to much for some people to buy and operate an air conditioner?

The Health Sector Assessment noted that, "Adaptation is a function of numerous societal variables, including financial resources, technical knowledge, public health infrastructure, and capacity of the health care system, all of which depend to some degree on competing demands and on the political, social, and economic climate" (Bernard and Ebi 2001). The remaining challenge is to better understand the importance of, and potential changes in, many of these societal variables in order to evaluate the effectiveness and costs of potential adaptive responses. Implementation of effective adaptive responses requires consideration of several factors (Scheraga and Grambsch 1998). First, adaptation comes at a cost. The scarce financial resources used to adapt to climate change could be used for other productive activities. In the vernacular of economics, there are opportunity costs to using scarce resources for adaptation. These costs must be carefully weighed when considering the tradeoffs among adapting to the change, reducing the cause of the change, and living with the residual impacts (Shriner and Street 1997). The ability of vulnerable populations (*e.g.*, the elderly) to incur the costs of a particular option must be evaluated when choosing among options.

The lesson from this example is that very specific types of information are required from assessments to enable decision makers to implement effective adaptative responses. In order to identify the specific nature of the information required, the clients for the information must be consulted from the outset of the assessment process. In this example, health officials need to know the potential costs of alternative adaptation options, who might bear those costs, and the ability of different demographic groups to pay. Ultimately, the decisions concerning what to do are value judgements and should be made by policy makers to reflect society's interests.

Example 2: Enabling Air Quality Managers to Cope with a Changing Climate

The Health Sector Assessment noted that ambient levels of regulated air pollutants have generally dropped since the mid-1970s in the United States. Yet air quality in many parts of the country falls short of current health-based air quality standards.

7 However, the relationship between winter weather and mortality has been difficult to interpret. The net effect on winter mortality from climatic changes is uncertain and the overall balance between changes in summer and winter weather-related deaths is unknown.

For example, in 1997, approximately 107 million people lived in counties that did not meet the air quality standards for at least one regulated pollutant.

Climate change will likely affect these conditions since air pollution is related to weather both directly and indirectly. Climate change may affect exposures to air pollutants by affecting weather and thereby local and regional pollution concentrations; by affecting anthropogenic emissions; by affecting natural sources of air pollutant emissions; and by changing the distribution and types of airborne allergens. Yet, the specific type of change (local, regional, or global), the direction of change in a particular location, and the magnitude of change in air quality that may be attributable to climate change are not known with certainty.

Uncertainties exist, including our understanding of the relationships between weather and air pollution concentrations, the combined effects of temperature and humidity on air pollution, and the effect of weather on vegetative emissions and allergens. For example, it is known that increased temperatures may enhance the formation of ground-level ozone, particularly in urban areas. But there are other factors that will influence ozone concentrations, such as average daily wind speed and precipitation. The effects of climate change on these other factors are highly uncertain.

Despite the existence of uncertainties, the assessment community must evaluate the adequacy of current air quality regulations in the context of a warming world. Exposures to air pollution have serious public health consequences that may become more serious as the climate changes. The challenge for the assessment community is to now consider how climate change might affect the ability of urban areas to meet air quality standards, and thus to protect public health.

The Health Sector Assessment concluded that adaptation measures include ensuring the responsiveness of federal and state air quality protection programs to changing pollution levels. But further insights are needed. What might air quality managers do differently today, if anything, to protect air quality and public health as the climate changes? This is a classic problem of decision making under uncertainty. But unless this additional analysis is done, the insights gained from the National Assessment will have limited usefulness for air quality management decisions in the United States.

Example 3: Enabling Coastal Zone Managers to Prepare for Sea Level Rise in the Mid-Atlantic Region

The lead authors for the Mid-Atlantic Regional Assessment also addressed each of the four questions posed in the U.S. National Assessment (Fisher *et al.* 2000). They reviewed the current status of the Mid-Atlantic region's environment and economy. In collaboration with stakeholders, they identified potential impacts of climate change and sea level rise on human health, fresh water quantity and quality, agriculture, forests, fisheries, coastal zones, ecosystems and recreation as being of particular concern in the Mid-Atlantic region. They then evaluated, to the extent possible given current scientific uncertainties, the potential consequences of climate change for each of these outcomes. And they identified key research gaps (Table 2).

Table 2. Research needs identified by the Mid-Atlantic regional assessment.

(1)	Improve projections for frequency, timing and intensity of average and extreme weather at a regional level
(2)	Improve projections of how average and extreme weather affect agriculture, forests, fresh water quantity and quality, coastal zones, ecosystems, and human health, and how adaptation would moderate negative impacts and enhance opportunities.
(3)	Improve models to evaluate benefits and costs of alternative adaptation options
(4)	Improve methods for evaluating how proposed shifts in policy (*e.g.*, land use policy) might affect vulnerability to climate variability and change.

The assessment provided important insights about the potential consequences of sea level rise for coastal zones (Figure 1) (Najjar *et al.* 2000). Higher sea levels will raise storm surge levels, even if the frequency and intensity of storms do not increase. One hundred year floods will occur every 25 to 30 years, and the same strength storm will cause more damage. Such storms can disrupt transportation, settlements, waste treatment, emergency services, and ecosystems.

The assessors state that they anticipate that society will continue to support structural approaches to protect ocean coastal areas, *e.g.*, beach replenishment, groins, and sea walls to maintain the status quo. They foresee coastal management repeating the inland flood plain experience on the Mid-Atlantic coast: federal subsidies for occupation of dynamic and sometimes hazardous coastal zones; structural answers to control coastal hazards and the impact of sea-level rise; and ever-increasing vulnerability with losses increasing along with investments in protection.

Although useful, the Mid-Atlantic assessment team realized these insights do not provide coastal zone managers with sufficient information to implement effective, site-specific adaptative responses in anticipation of future sea level rise. It is not sufficient to say that structural approaches will be needed to protect coastal areas. It's also important to understand their cost, the public's willingness to pay that cost, the likelihood that the adaptation measures will work, and the impact of the adaptation measures on the quality of life. To begin to understand and meet these information needs, the assessors are returning to the stakeholders, via workshops and surveys, to share what they have learned and elicit from the stakeholders their interests and concerns, as well as to begin to understand the public's willingness to pay to adapt.

The salient question for coastal zone managers is what should be done differently today, if anything, to plan for more frequent future storms, despite the uncertainty about the timing of storm events? (Alternatively, what strength of evidence is needed from the assessment community for coastal zone managers to change their current practices?) Once again, this classic problem of decision making under uncertainty still needs to be addressed by the assessors.

Example 4: Enabling Public Health Officials to Cope with Vector-Borne Diseases

The Health Sector Assessment also examined the potential implications of climate change for the spread of vector-borne diseases in the United States. Several useful insights were gained. First, it was observed that in some cases, specific weather patterns over several seasons appear to be associated with increased transmission rates. For example, in the Midwestern U.S., outbreaks of St. Louis encephalitis

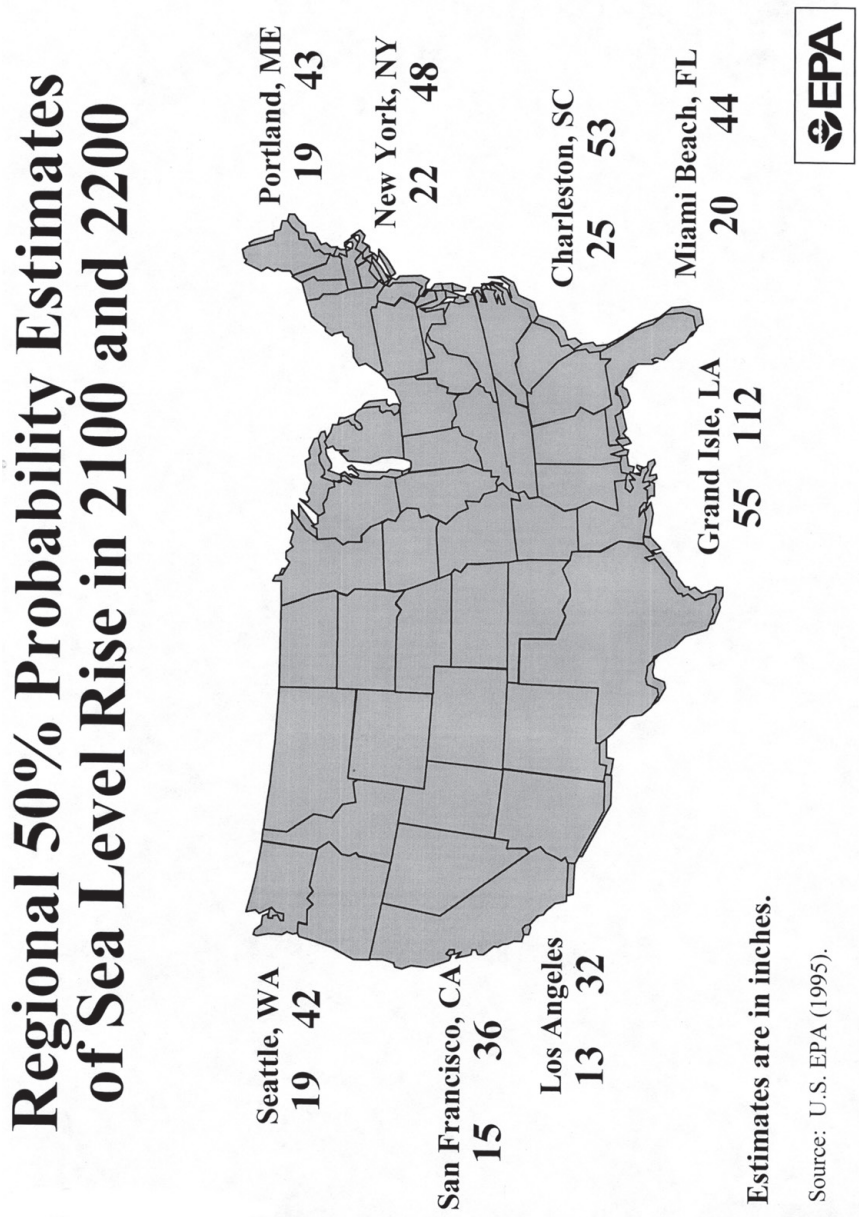

Figure 1. Regional 50% probability estimates of sea level rise in 2100 and 2200.

appear to be associated with the sequence of warm wet winters, cold springs, and hot dry summers. It also was noted that one scientific study for the western U.S. predicted that a 3 to 5°C increase in average temperature may cause a shift in distribution of both Western equine encephalitis and St. Louis encephalitis outbreaks — based on the temperature sensitivity of both the virus and mosquito carrier.

Second, tremendous growth in international travel increases the risk of importation of vector-borne diseases. Some diseases can be transmitted locally under suitable circumstances at the right time of the year.

From these insights the Health Sector authors drew several conclusions. First, a high standard of living and well-developed public health infrastructure are central to the current capacity to adapt to changing risks of vector- and rodent-borne diseases in the U.S. Second, the probability of transmission of vector-borne diseases may or may not be increased by higher temperatures and changes in precipitation. Therefore, maintaining and improving the existing public health infrastructure — including surveillance, early warning, prevention, and control — remain a priority.

The challenge for the assessment community is now to evaluate the effectiveness of potential adaptive responses to these risks. As noted earlier, adaptation comes at a cost, and the opportunity costs of resources expended to deal with these risks must be considered. Also, maladaptation can result in negative effects that are as serious as the climate-induced health effects being avoided (Scheraga and Grambsch 1998). An adaptive response that is made without consideration for interdependent systems may, inadvertently, increase risks to other systems that are sensitive to climate change. One possible adaptive response to the risk of vector-borne diseases is the use of pesticides for vector control (WHO 1996). However, the effects of pesticides on human health and insect predators and increased insect resistance to pesticides all need to be considered and assessed if new pesticides are used to control disease vectors. New chemicals or treatments for vector control not only need to be effective, but their breakdown products should be non-toxic and non-persistent.

The assessment tells us that we can limit the risk of vector-borne disease, but that some — though not all — adaptation measures bring risks of their own. Many adaptation measures can have diverse implications for different segments of society and the environment and, as such, their evaluation and implementation can be complex. A complete policy-focused assessment will lay out these adaptation options and their associated risks. A well-informed decision maker will evaluate the relative risks and decide how to respond in order to reflect the interests of the public.

SETTING THE RESEARCH AGENDA: PRIORITIZING RESEARCH

Assessment and basic scientific research are complementary, but different activities. Scientific research — whether in the physical, biological, economic, or social sciences — helps to identify new risks or opportunities and provides information and data required for an assessment. In turn, assessments help identify and prioritize research needs that must be filled in order to better answer questions being asked by the stakeholder community. Constant feedback between these parallel processes is essential.

The last step in any particular assessment is the identification and *prioritization* of "key" research gaps, *i.e.*, those knowledge gaps that must be filled in order to answer stakeholder questions. Some of the stakeholder questions will be the same as those asked at the outset of the assessment process. But the stakeholders may have new questions they wish to pose, either because of the insights they have already gained from the assessment process or because of changes in other factors unrelated to the assessment process. For example, stakeholders involved in the Health Sector Assessment have raised new questions about the potential effects of climate change on the frequency of severe weather events and resulting accident fatalities.

Since the resources available for conducting research related to an assessment process are scarce, research needs must be prioritized. Research dollars that are available to support assessments need to be directed to their highest-valued uses, *i.e.*, toward producing timely research products that fill "key knowledge gaps" that are needed to answer stakeholders' questions. This requires that *value of information* calculations be done (either explicitly or implicitly). Such calculations yield insights into the incremental value to stakeholders of information expected to be derived from an investment in a particular research activity. The results of these calculations depend on changing stakeholder needs and values, and the timeliness and relevance of information. Value of information exercises can be expensive to undertake, but need to be part of any assessment process.

A remaining step for many of the regional and sectoral assessments conducted as part of the first U.S. National Assessment is the prioritization of research needs. Both the Health Sector Assessment and the Mid-Atlantic Regional Assessment identified research needs at the end of their first assessments (Tables 1 and 2). However, both assessments still need to prioritize the research needs.

CONCLUSIONS

Policy-focused assessments must be based on, and often driven by, a sophisticated understanding, not just of the uncertainties from scientists' perspectives, but also the uncertainties as seen from the perspectives and jurisdictions of decision makers for whom the assessment is intended. The questions for research and assessment must have a scientific "push." But they must also have a societal "pull" that is based on a different vocabulary and conceptual framework. These frameworks require rigorous consideration.[8]

Policy-focused assessments are an important tool for addressing complex, global environmental problems. The U.S. National Assessment is an excellent example of an ongoing, analytic process that is stakeholder-oriented to ensure the relevancy and timeliness of results, and is multidisciplinary in nature. The assessment has already provided useful insights to policy makers, resource managers, and other stakeholders. However, further effort must be made to translate the insights gained from the initial stages of assessment into guidance for policy makers. Ultimately, the assessments must help resource managers and other decision makers determine what they should do differently — or the same — today to plan for future climate change.

8 This helpful observation was made by an anonymous reviewer of an earlier version of this manuscript.

The U.S. National Assessment — including the regional and sector assessments – has also identified knowledge gaps that are useful input to the development of an agenda for future climate-related research. However, value of information calculations still need to be done to prioritize the research needs. Such an undertaking will require that assessors partner with their respective stakeholder communities since the results of these calculations depend on changing stakeholder needs and values, and the timeliness and relevance of information.

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